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Sanitary Construction and Protection of Wells

By H. J. Ongerth

THE importance of wells as a source of water supply in California was demonstrated in a recent survey by the State Bureau of Sanitary Engineering (1), in which it was shown that 287, or 77 per cent, of the 373 public water supplies surveyed derived all or a major part of their supply from wells. Excluding Los Angeles, San Francisco and the East Bay communities, all of which depend mainly on surface sources, these well supplies serve 75 per cent of the population in the places surveyed.

The value and need of protecting underground sources of water are factors often overlooked by water works men. That protection is necessary is forcefully indicated in the report of Gorman and Wolman (2) on water-borne outbreaks. In their survey they found that 36 per cent of all water-borne outbreaks in the United States, between 1920 and 1936, were caused by pollution of underground sources of supply, these outbreaks involving more than 18,500 cases of typhoid, dysentery and diarrhea.

Wells may be, and often are, so located and constructed that they may at any time, under unfavorable conditions, become dangerously contaminated. The mere fact that no water-borne illness has occurred, or that the few water samples collected have shown no contamination, all too easily develops a false sense of security among those responsible for the supply.

Protection of wells may logically be separated into three major phases: (1) selection of site with respect to environment; (2) subsurface construction; and (3) surface construction. No one of these phases is dom-

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A paper presented on October 23, 1941, at the California Section Meeting, Fresno, Calif., by H. J. Ongerth, Asst. San. Engr., State Dept. of Public Health, Berkeley, Calif.

inant—all three must be considered in any case. Selection of site with particular reference to underground pollution, however, is least susceptible to orderly analysis.

Selection of Site

Wells must, of course, be located with respect to points of intended use and availability of underground waters. In the central valleys of California deep wells will produce water in almost any location and, therefore, are generally drilled near the point of water use. Wells so placed are usually near potential sources of subsurface contamination. This contamination, originating in the facilities for sewage disposal from the point of water consumption, has its source in sewers, septic tanks, cesspools and privies. In locating a well there arises the question of allowable proximity of the well to the nearest known sewerage system. There is no one definite answer to this question, but a knowledge of the extent and direction of travel of underground pollution and its relation to the ground water level will aid in providing a reasonable one.

Perhaps the best information on the subject is the report by the U.S. Public Health Service Hygienic Laboratory (3) presenting the results of a series of experiments on the extent and travel of underground pollution. This study was made in a slowly moving ground water table and a medium of rather fine, sandy soil. Experiments established the fact that, as pollution traveled, it did not expand laterally, but, on the contrary, appeared to contract. The direction of travel was only in the direction of flow of ground water and pollution was traced as far as 232 ft. from the source.

Generally, normal subsurface flow is toward adjacent watercourses or essentially parallel to the surface of the ground. There are, however, exceptions to this rule, so it should not be depended upon too greatly. Moreover, the rate of pumpage of wells may be a factor, since, in some wells, where the draft is heavy, a greatly increased drawdown may result. The cone of depression which accompanies such a drawdown may reverse the direction of underflow. Formulas on well hydraulics make possible the determination of the extent of the cone of depression. In fractured rocks, granite and the like, and in lavas and limestones, the direction and extent of underground flow cannot be determined with any accuracy. In such formations construction of the well provides the only protection against contamination, and type of construction should be selected with extreme care.

For esthetic as well as sanitary reasons, wells should be placed on department-owned lands large enough to provide safe distances from such things as rabbit hutches, chicken yards, and manure piles. A clean en-

vironment is a valuable asset when considering consumer relations. Wells located without regard to esthetic aspects are apt to be regarded by the users with suspicion. A case in point is the location of wells immediately adjacent to cemeteries. One such well, probably safe bacteriologically but open to serious objection by the consumers, was abandoned.

Wells located in California coastal plains have generally been drilled in or close to watercourses as the only means of securing an adequate supply. Such wells are frequently vulnerable to surface flooding. Emphasis should be placed on drilling wells above known flood levels. The application of simple engineering principles concerning stream flow measurements and high water marks in flood planes provides important, though often neglected, data on the possibility of the flooding of a given site. Wells located without regard to slope of land may be subject to overtopping due to surface runoff not associated with recognized water channels. When it is necessary to locate wells in areas subject to flooding, positive means should be provided to prevent overtopping and resulting contamination of the well.

Types of Wells

Well construction provides a second line of defense and its importance should never be neglected or overlooked regardless of the environment. The simplest type is the dug well which can be dismissed from consideration because of the difficulty of obtaining safe water from it. Dug wells usually draw water from the soil zone, which is most likely to be polluted. Though in some cases attempts are made to cut off this inherently dangerous upper strata, it is difficult to accomplish this, and absolute security can never be assured. Gorman and Wolman showed that by far the greatest number of water-borne outbreaks due to well pollution fall in the class of surface pollution of shallow wells.

Driven wells, like dug wells, collect rather shallow waters. They usually consist of a screw pipe with strainer at the lower end, water being drawn only from this point. The most commonly used well is the cased well, drilled or bored (there being no difference from a sanitary standpoint). These may be classified under two types, the gravel-envelope well and the ordinary casing well. Both involve the use of a metal cylinder or casing.

Gravel-envelope wells may be used for one of two objectives: to collect a maximum amount of water for a given depth of well or to shut out sand and prevent the cave-in of unconsolidated formations. Gravel-envelope wells used for the purpose of obtaining the maximum amount of water inherit some of the objections to the dug well, resulting in a lowering of sanitary standards. Gravel-envelope wells constructed to hold out fine sand are probably as satisfactory as an ordinary cased well, with the ex-

ception that those drilled by the hydraulic-rotary method involve the use of drillers mud. It is difficult to clean up such wells following their completion, even with heavy chlorination, and considerable time may elapse before negative laboratory results can be obtained.

Subsurface Construction

Although casings were, no doubt, first used to support the well, they have an equally important function in preventing the entrance of water except from intended strata. The continuous performance of this function depends upon the type of casing and upon its ability to remain intact throughout the life of the well. Certain casings have inherent weaknesses which must be considered. In offering these comments, however, it is not meant to imply that these are the only important types of casing.

Perhaps the best casing is that made of wrought iron with screw joints. Slip joint casings are less desirable because riveted or spot-welded seams and joints are not as positive against leakage as a solid screw casing (though an all welded casing may be almost equal to a screw joint casing), and because rough handling in driving may spring the casing and cause it to leak. Single slip joint casings should not be considered for public water supplies. Some wells are constructed with inner and outer casings and a cement-mortar annular ring poured between the two. If the mortar is carefully poured so that segregation does not occur and if placed to a sufficient depth, all possibility of entrance of surface water to the well is obviated.

The ability of a given casing to remain intact depends upon the material and gage of the casing, and a combination of factors which lead to or retard the external corrosion of the casing. Material of casing is fairly well standardized, being usually either red hard steel or wrought iron. There is no generally accepted standard of gage of casing. For slip joint casings, one authority (4) recommends the following gages: for 12- to 16-in. wells, 10- or 8-gage casing; for wells over 16-in., 8-gage casing. These weights are said to provide proper rigidity and offer a fairly long life against corrosion.

External corrosion of casing, leading to failure and subsequent entrance of polluted ground water, is a serious problem in some localities. If corrosive soil conditions exist, steps should be taken to increase the gage of casing or, more effectively, to provide a concrete annular ring. Dependence should not be placed solely upon locating the well away from sources of pollution, since, in the life of the well, the adjacent territory may be developed. A possible exception is when the water department owns and retains a large plot of land around the well.

The level of perforations is dictated by location of available suitable water strata and relation of upper ground water table to pervious upper

strata. Since construction of a casing capable of remaining tight has been emphasized, perforations, obviously, should not be placed in the level of the upper ground water strata. Gravel-packed wells with no outer envelope, in which a gravel annular ring extends from top to bottom, are in effect perforated for the entire depth. This type of well may be protected, however, by the use of a "conductor" pipe, a few inches larger in diameter than the casing, extending into an impervious strata below the upper ground water table.

Surface Construction

In the past, too little attention has been given top construction of wells. It is pointless to provide adequate means of subsurface protection when surface pollution may easily enter through the top of the well. A rather comprehensive discussion of this subject may be found in the Progress Report of the Committee on Ground Water Supplies, Conference of State Sanitary Engineers, 1936 (5).

Perhaps the most serious defect is the construction and termination of the casing in a pit. The use of pits in old well installations is rather common. This development was brought about because centrifugal pumps, as formerly used, were limited to suction lifts of about 25 ft. Where water levels were below this, depth pits were dug, commonly exceeding 10 to 30 ft. Many of these old centrifugal pumps have been replaced by deep well turbines set at the bottom of such pits. For good sanitary control, in this circumstance, the casing should be extended to the ground surface and the pit backfilled, preferably with clay. In the present day, deep wells pumped by turbines are sometimes located in shallow pits for convenience of pump discharge piping arrangements. Various states, however, prohibit the use of pits (6, 7). Of interest are the requirements of the Minnesota Department of Health which, in part, are as follows:

"*Pump pits:* Pump pits or sub-level pump rooms either drained directly to a sewer or provided with a sump and ejector apparatus are always subject to flooding and are considered dangerous. Pits require special drainage systems which often get out of order. Leaks in the well casing at a time when the pit is flooded would permit contaminating material to get into the well. . . . No well head, well casing, pump, pumping machinery, valve box connected with a suction pipe or exposed suction pipe should be located in any pit, room, or space extending below ground level, or in any room or space above ground which is walled-in or otherwise inclosed so that it does not have free drainage by gravity to the surface of the ground."

Existing pits should be provided with an adequate sump pump, the discharge of which must have no physical connection with any sewer system. The most serious water-borne typhoid epidemic on record in California was

the Santa Ana epidemic, which was traced to an overloaded sewer backing into a forgotten drain leading from a well sump.

Wells located in flood planes must be protected against overtopping. A simple and satisfactory protection is to extend the casing and concrete pump base above known flood levels. A good example of this may be found in the Watsonville, Calif., water system, where, in 1940, a well drilled in the flood plane of the Pajaro River was constructed with the casing and pump block extending 6 ft. above ground level, and 2 ft. above the highest recorded flood level. A unique means of protection against flooding is through use of the submersible deep-well turbine. Such an installation has been utilized by the city of Oceanside, Calif., where, in 1940, a deep well was drilled in the bed of the San Luis Rey River above normal channel. Top construction is built to withstand the impact of floods and to remain tight while covered with flood waters. In a few cases, river bottom wells are found similar to those in use at Paso Robles, Calif., where centrifugal pumps, located on the bank of the Salinas River, draw water from several wells through a common suction. The connection between each suction and casing is watertight, the only objection being that, should leakage occur during floods, it would not be possible to detect entrance of small amounts of flood water.

In all wells, the casing should be extended a few inches above ground level to the top of a pump block. The connection of the pump to the casing should always be watertight, best made with a bolted flange. Wells not effectively sealed may be subject to drippage, wind-borne contamination or even open to small animals. Such wells may have difficulty in meeting present day bacterial standards. Frequently, there are openings into the casing for purposes of measurement of water levels, air release, etc. In the case of gravel-envelope wells a tube extends up from the annular ring to permit addition of gravel as sand is pumped from the well. In each case such a connection should be made with a screw pipe extending well above the pump house floor and should be provided with a tight screw cap.

Water-lubricated pumps which require a source of water for lubrication, while the pump is being started, should have a tight covered metal tank for this purpose. With oil lubricated pumps, leakage of oil from the lower bearings may result in positive samples. Careful maintenance is the best insurance against this occurrence.

Last but not least, a gooseneck sample cock should be provided at some convenient point on the pump discharge line close to the well. Anyone who has attempted to trace contamination in a water system will always give this point careful consideration.

The purpose of this paper has been to offer a few comments on protection of wells rather than to present a complete text on the subject. No attempt has been made to set up standards, but rather to point to lines of approach to a problem which many water works must face. The variables are many and each case must be decided on its own merits rather than by arbitrary standards formulated to meet all conditions.

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An Engineer's View of Well Drilling Contracts

By E. Arthur Bell

OF PRIMARY importance in planning the drilling of a well is that the engineer avail himself of all the facts pertinent to the choice of the proper type of well for the particular situation encountered, and that such factors as geology and topography of the area be given full consideration in the choice. Following this, it is important that he limit bidding on the job to well drilling contractors who specialize in the construction of the type of well desired. And, finally, because price is such a determining factor in the selection of the contractor, the engineer must know how to prepare contracts and specifications that will protect his client if the employed "lowest bidder" is unqualified.

In the great majority of cases, the first two of these requirements are met without difficulty, but the last has been a constant source of trouble; and, because contracts and specifications are the groundwork of the job itself, the problem is a serious one.

It is this problem which the author proposes to discuss here in the hope that the information he has gained may be of aid to those engineers who, like himself, have a limited knowledge of well drilling, and who are charged with the acquisition of new or additional supplies of water from subsurface sources as a part of their normal duties.

Types of Contracts

Of the innumerable types of well drilling contracts, only those which appear to the author to be most important will be discussed. It should be pointed out, too, that the sequence used is not to be construed as the order of importance of the various types, as each has its particular advantages or disadvantages for any given situation.

Guaranteed Minimum Supply Contracts

In "guaranteed well" contracts the prospective driller is charged with obtaining a supply of water from a site to be chosen either by him or by

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the client. The driller is paid only if the well yields the minimum supply specified in the contract. Price in such a contract is usually determined by a lump sum bid for the completed well specified to deliver a certain minimum quantity of water, with a bonus agreement to provide for delivery above the specified minimum.

The main advantage of this type of contract is that the client is assured of a specified minimum supply for a definite sum of money. The disadvantages are: (1) that a site desired by the driller may be impossible to procure and one selected by the client may not yield water; (2) that the cost is necessarily high, because drillers include extra charges for their own protection in the original bids; (3) that the proper site may involve difficulties from an engineering standpoint that were not taken into consideration at the time the contract was signed; and (4) that the client is at all times "at the mercy of" the well driller. As one driller was overheard to say: "You contracted for a certain supply of water—how and when I get it is none of your affair." It need hardly be mentioned that the bond required should be sufficiently high to exclude bidders who are not financially responsible to carry out this type of work.

Unit Price Contracts

Contracts for "unit price" wells should be drawn up to provide that the engineer have complete control over all operations. Work done under this type of contract includes double-cased gravel filter wells, single-cased gravel wells, and double- and single-cased rock wells. Unit prices usually include cost per foot for a given diameter well complete, or cost per foot for drilling plus material and testing costs. The engineer should avoid giving a driller a *carte blanche*, as there are many loopholes in such an agreement.

The advantages of the unit price contract are: (1) that payment is made on the basis of actual footage drilled; (2) that better control of the operation is afforded the engineer or client; and (3) that the cost is usually lower than on the guaranteed minimum basis. Its main disadvantage is the possibility that little or no water may be found at a reasonable depth in one or more locations, so that the client is forced to gamble on the cost.

Per Diem Rate Contracts

A contract for drilling a well or wells at a fixed rate per day plus cost of materials may be a very simple one. In the writer's opinion, the specifications in such agreements are more important than the formal contract terms. This type of contract involves the greatest gamble on the part of the engineer or client and, therefore, should be entered into with care.

Experience has shown that the selection of the proper driller may be of advantage to the client, both from a financial and an engineering standpoint. In this type of contract the driller is not involved in any gamble and, consequently, usually does a better job. An inexperienced driller, without adequate equipment, might, however, prove to be a great liability. The engineer should draw the specifications so carefully that only qualified drillers would be considered for the job. In making a selection among drillers, the legal method of prequalification of bidders should be used. This method is valuable for all types of contracts, but is an absolute requirement with the per diem rate type.

The cost of a well drilled under a per diem rate contract may in some cases be higher than under any other type, but many engineers have testified to the fact that it is the most satisfactory type in the long run.

Other Types

Contracts of other types include those made directly between the well driller and the client. This is usually done to eliminate the cost of the engineer's fee and sometimes proves entirely satisfactory. In this respect too, however, the well driller's integrity is the key to the situation. Such contracts should be avoided if the bidding is to be competitive, as the lowest bidder is very often the poorest qualified.

Contract Specifications

In closing the author would like to offer his suggestion of what should be included in a list of specifications for any well drilling contract. Some of these points may be controversial, but, in general, they are the details which must be provided for if the contract is to give the engineer definite assurance of performance.

1. Prequalification of bidders (If prequalification is not desirable, specifications should be worded to exclude drillers without sufficient experience and without adequate equipment.)
2. Complete control of work by the engineer and his client
3. Well to be plumb
4. Casing material not to disintegrate in soil
5. Casing to be sealed to exclude surface water
6. Screen to be non-corrosive
7. Accurate log to be kept
8. Care to be taken in preserving stratification of soil encountered (no breakdown or caving)
9. Proper development of well
10. Testing
11. Guarantee of workmanship.

Relationship Between the Well Drilling Contractor and The Owner

By E. D. Every

THE relationship between the water well contractor and the well owner is complicated by the summary opinion of a large number of water works men that the owner is "good" and the contractor "bad." Admittedly, in some instances, this may be true, but to say it is always so is patently unfair. The legend of the dishonesty and incompetence of contractors in general has developed in large part from mutual mistrust based on a lack of understanding on the part of the owner and his engineering consultant. In other words, the "good" and "bad" of the relationship are probably equally divided between the two groups, and praise or blame must be judged on the basis of the individual case.

One of the main difficulties in the relationship is the practice of the owner in either planning the well himself on a minimum of knowledge or entrusting the planning to an engineer of established reputation who is not versed in the special problems of underground water development. In many instances the problems and difficulties which arise from following the specifications of the owner himself or of such an engineer are attributed to the contractor's incompetence, and *ergo*, he is "bad."

Examples of this practice are easy to find. In a recent well sinking job in New Jersey, the consultant, an outstanding industrial plant engineer, insisted that an air lift test would give more reliable information than the deep well turbine pump test. After the well had been completed and properly tested with the deep well turbine pump, he spent more than $600 for a weir box and air lift test, the result from which was the same as that of the turbine pump test. In this case the owner was satisfied because he did not know what had happened, but had he known, the contractor no doubt would have been called to task. In another case, a leading road building engineer, with the contractor's test log (giving static level and drawdown) in hand, complained to the owner that the test was not prop-

A paper presented on October 17, 1941, at the New Jersey Section Meeting, Atlantic City, N.J., by the late E. D. Every, Pres., Artesian Well & Equipment Co., New York.

erly made, as the pumping level was not known. In still another case, a good sewage disposal plant engineer specified a pressure tank and deep-well turbine-type centrifugal pump for a well with a 60-ft. static water level, in addition to which he installed an air compressor with a 2-hp. motor to maintain air volume in the pressure tank, when all he would have needed to rid the tank of the excess air produced by frequent starts was an automatic air release or volume control valve, costing about $3.

These are but few of many examples which point to the need for a realization that the development of underground water is a highly specialized art, which demands the services of contractors and engineers qualified by practical experience. Only if the contractor and engineer have such training does the client receive the service he has a right to expect. In the last analysis it rests with the owner to choose the personnel; so it is he who should be educated to the need for specialists—a specialist in well engineering through whom he would automatically get a competent contractor, or, if he prefers to deal directly, a specialist in well construction. Although the proper choice of personnel is not an absolute insurance against trouble, it will limit the difficulties to those which are unavoidable because of the nature of the task and will definitely assure the owner of fair treatment and minimum expense.

These are the basic issues involved in the relationship between the contractor and the owner. In practice, friction between the two parties, both as a cause and an effect of the apparent mutual mistrust, manifests itself in a number of different ways.

Other Examples of Friction

When an owner deals directly with the contractor, he often awards the contract on the basis of the contractor's specifications. In many cases, of course, this is an entirely satisfactory arrangement, fair to both parties; but it is not always so. Because an unscrupulous contractor can work this arrangement to his own advantage, it is not a safe practice for the owner. In one case, of which the author knows, where an owner desired a certain yield from a well, the specifications and contract were prepared by the contractor so that the owner understood that he was being guaranteed the desired yield from a well 250 to 300 ft. deep, at $5 per foot. Actually, though there was an absolute guarantee of yield, there was no limit to depth, the contractor having figured that his cable was longer than the owner's pocketbook.

On the other hand, the owner is often at fault for not consulting the contractor at the beginning of a project in which he is later to be involved. In one such case, a site was purchased and an industrial plant built and equipped at a cost of approximately $1,000,000. When construction of the

plant was almost completed, the problem of water supply was taken up with a well contractor, who reported that it would be impossible to obtain a sufficient supply. Because the investment was so large, however, the contractor was instructed to do his best to develop a supply, an emergency connection being made to the city water supply temporarily. For 18 months, the owner paid the contractor for his work and paid for the city water, and at the end of that time the plant had to be abandoned because the high cost of water made operation unprofitable. Had the contractor been consulted before the site was purchased, the entire loss could have been avoided.

Among the basic causes for unfriendly relations between owners and contractors should be included the fact that the owner usually strives to drive a hard bargain. When in doing this the price set is too low for the work involved, the contractor must find some way to reduce his own costs, lowering the quality of his work. Thus, the relationship becomes a contest, and one which the contractor usually wins, because it is his game. Any number of examples of the unscrupulous practices devised in this "game" can be cited, but suffice it to say, here, that most of them are perpetuated by the general practice of awarding contracts to the lowest bidder, without considering the other factors involved.

Improvement of the Relationship

The problem at hand is to do something to improve the relationship. In New Jersey, the Well Contractors Association has sponsored legislation (without success so far) to have the contractor licensed by the state. There is no question but that such a law would be of great benefit to the public. It would give owners real protection, and, in time, would place the contractors in a position of confidence.

Examples of the need for such a law are unnecessary, but one case is worthy of mention. Recently a contract was awarded for a well, the sole purpose of which was to take the overflow of a cesspool, in an area where many rock wells were in daily domestic use. On the contractor's refusal to accept responsibility for such construction, a written permit to proceed with the work was issued by a local board of health. The contractor then turned the matter over to the State Board of Health, asking for a rescinding order—which was issued. Photostatic copies of the transaction were mailed to every state senator as an argument for passage of the bill.

Until such a time as the bill is passed, however, the best recommendation for an improvement in the situation is that municipalities and owners select well contractors on the same basis as they select their engineers and other professional workers, rather than adhering strictly to the "lowest bidder" system of awarding contracts.

Development of Deep Wells by Dynamiting

By Ralph E. Milaeger

IN RECENT years it has been proved that the dynamiting of deep-well water-bearing formations in most cases increases capacity and raises pumping water levels, i.e., increases the "specific capacity" of the wells. The data given in this paper show conclusively that the cost of dynamiting, which is but a small fraction of the total initial investment, is more than paid for in a few years by the improved pumping conditions.

In discussing the theory of ground water movements relative to dynamiting, the following terms should be defined:

Ground water—any subsurface water

Specific capacity—well yield, in gallons per minute per foot of drawdown

Aquifer—the underground water-bearing formation that acts as a reservoir and a conduit for the ground water.

In general, water particles move through the water table from the point of intake to where they will eventually be discharged into some water-course through a subterranean spring or to where they will be absorbed by the root of some plant. The path of the particles may be short and direct or long and devious, traveling hundreds of miles and to great depths. Their rate of movement has been determined by the use of salt and dyes. To date the fastest movement observed has been 420 ft. per day, and the slowest, 0.1 ft. per year; though the range is undoubtedly even greater than that. In the water-bearing formations in which wells are usually placed, however, the range is generally limited to between 5 ft. per day and 5 ft. per year.

The quantity of water stored in the interstices of water-bearing formations is much greater than that existing in lakes, streams and the atmosphere, although much less than in the oceans. Investigations have shown,

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A paper presented on October 8, 1941, at the Wisconsin Section Meeting, Racine, Wis., by Ralph E. Milaeger, formerly Water Supply Engr., Milaeger Well Drilling Co., now Water Waste Inspector, U.S. Engr.'s Office, War Dept., Boston, Mass. This paper is an excerpt from a Bachelor's thesis, entitled, "Modern Deep Well Practice," submitted to the Civ. Eng. Dept. of the Univ. of Wisconsin in June 1941. A copy of the original thesis is available for examination by those interested, from the author.

for instance, that the Carrizo sand in a 60-mile stretch in the winter garden region of Texas transmits about 24 mgd. at an average velocity of about 50 ft. per year. Much of this stored water, however, is not economically available for use.

Properties of Aquifers

Aquifers perform two main functions, acting as reservoirs and conduits. In all accurate studies of ground water these two functions must be recognized and differentiated. Circulation of the water in the aquifer varies inversely as its content of mineral matter and salts.

If there were no intake or recharge into the formations, the ground water systems would gradually become exhausted, but, as an integral part of the hydrological cycle, their replenishment is assured. Rain and snow descend upon the earth and part of the water finds its way down into the water table. This new water then goes into storage in the aquifer, the water table is built up, the head increased, new energy supplied and movement of the ground water continues.

To make possible the flow of water into a well there must be a net differential between the pressure in the aquifer and that of the atmosphere. This pressure differential will tend to force the water to rise, in the well tapping the aquifer, to a height equal to the net differential head after losses of friction have been subtracted. Where the head is greater than the depth of the well, a flowing well will result.

The two fundamental physical properties of any aquifer, which largely control the movement of water through it are: (1) the ease with which it transmits water; and (2) the amount of water that will be released from storage when the differential head in the aquifer is reduced.

When water is pumped from an artesian aquifer, a *cone of pressure relief* is developed around the top of the well. Though this is not permanent, the recovery of most wells is slow and incomplete. If pumping is discontinued temporarily the cone may disappear due to percolation of surface waters into the ground, plus the partial draining of adjacent formations. If the cone grows beyond the immediate vicinity of the well to cover a large area, the condition is referred to as a *depleted pressure surface*, and is permanent. The capacity curves in Fig. 1 demonstrate the recession in capacity due to pumping off the cone at the start of the tests.

In southern Wisconsin and northern Illinois the sandstone aquifers, such as the St. Peter and the Potsdam, the latter being made up of the Dresbach and Mt. Simon, serve as reservoirs and conduits for water that has percolated through the overlying beds and seeped in at the outcrop. Dynamiting a well releases a tremendous explosive pressure which not only frees the water from its suspension in the interstices of these sandstone aquifers

but also causes large breaks and cavities in the stratum. Under the new conditions, more surface is exposed, allowing additional quantities of water to flow into the well.

Dynamiting Theory and Practice

Most dynamiting is accompanied by a large influx of sand into the well, which must be cleaned out before any testing can be done. In many cases, however, dynamiting has been accomplished successfully where little sand was loosened, even though the specific capacities were increased consid-

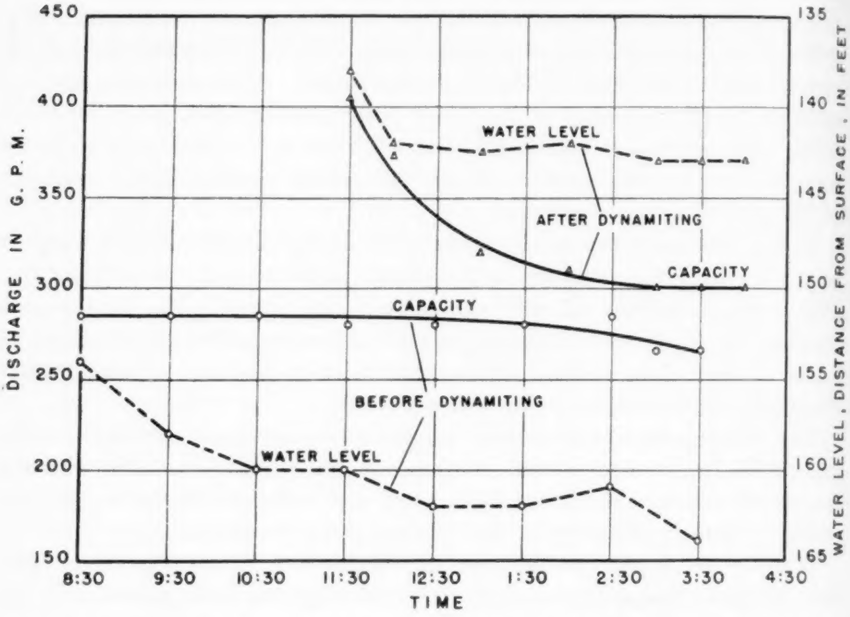

Fig. 1. Comparison of Water Levels and Capacities Before and After Dynamiting of a 1,001-ft. Well at Kansasville, Wis. (static level, 137 ft.)

erably. If the formation is hard, dynamiting will cause crevices which will allow water to enter the well more freely. Sandstone has a tendency to work into the well in large lumps, resulting in the formation of bridges at irregular intervals rather than a solid fill throughout the depth of the well.

One shot may consist of a charge of 25, 50, 75 or 100 lb. of dynamite, depending upon: (1) the size of the hole (the smaller the hole, the smaller the charge); (2) the character of the rock, e.g., the grain; (3) the rate of drilling, in feet per hour, taken from time reports; and (4) the depth of placement of the shot underwater, i.e., the amount of hydrostatic water pressure exerted on the dynamite. At least two dynamite caps should be

used to fire each individual shot so that explosion of the entire charge will be assured. The depth at which the shot should be placed and its magnitude will vary with the individual case. If the log of a nearby well is available, the state geological department will offer its advice on the correct placement of shots in the formation.

As an example of what may be accomplished by well dynamiting, data on a well at Kansasville, Racine County, Wis., which was drilled in August 1940, are presented in Fig. 1. It should be noted that the pumping lift was raised from 164 to 143 ft. and that the specific capacity increased from

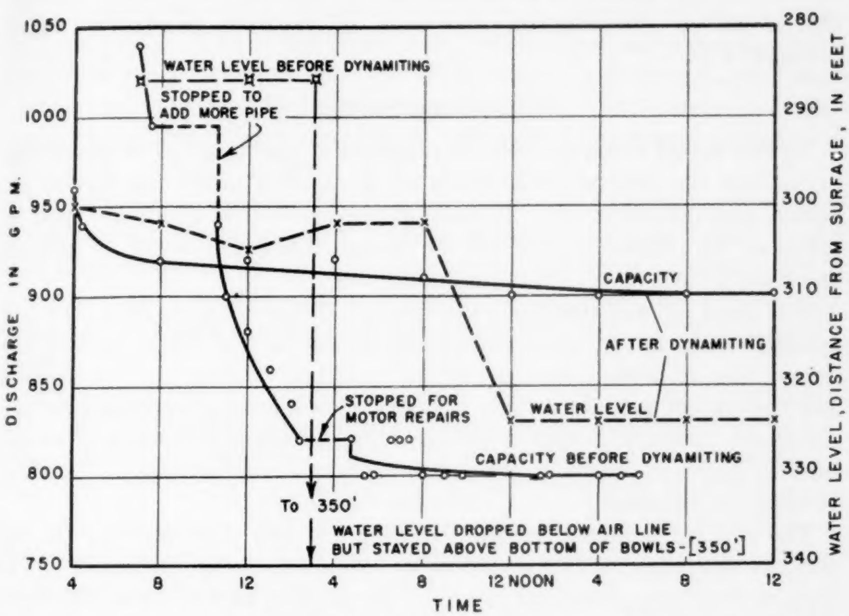

FIG. 2. Comparison of Water Levels and Capacities Before and After Dynamiting of a 1,825-ft. Well at Milwaukee, Wis. (static level, 164 ft.)

5.6 to 9.2 gpm. per ft. of drawdown. Two 50-lb. shots of 80-per cent dynamite were placed at 929 and 943 ft. in the 1,001-ft. well. After dynamiting, the capacity curve dropped from 400 to 300 gpm. in about 2 hr., a reaction typical of well discharge curves, being due to the aforementioned pumping off of the cone of pressure relief. The drop-off was unusually large in this case because it was augmented by sand infiltration which helped decrease the discharge. As is general practice, the contractor cleaned out the sand that filled the well immediately after shooting until the hole was returned to its initial depth. Usually, pumping of the well causes additional sand infiltration which must be removed after the test.

An examination of the curves from the tests at a well of a steel tube company in Milwaukee (Fig. 2) shows the remarkable improvement in capacity and pumping water level obtained by shooting the well with twelve 100-lb. charges. Before dynamiting, the water level dropped to below the bottom of the air line (350 ft.) with the pump discharging 800 gpm., and the capacity curve was very irregular. After dynamiting, however, the capacity was steady at 900 gpm., the maximum capacity of the pump, and the water level remained fairly steady at 322 ft. The specific capacity showed an increase from 4.21 to 5.70 gpm. per foot of drawdown; and the slight initial drop in the capacity curve, resulting from the action of pumping off the cone of pressure relief, was again demonstrated.

Costs and Savings

To give actual cost and probable results of a "shooting" job is impossible because of the unpredictable behavior of aquifers under the terrific explosive pressures involved. Because of these pressures, great care must be taken in the placement of shots far enough below the casing to prevent any damage to it or any shattering of the pipe.

It is usual for well contractors to bid on a dynamiting job on a time and material basis, i.e., to receive their pay on the basis of hours worked, the hourly rate to include the rent of the machine, the payment of workers and the cost of materials used. This method has an advantage over the lump-sum method in that it obviates the contractors' tendency to use inferior materials or to do work that is inefficient or inaccurate, in the effort to minimize expenses.

The savings resulting from dynamiting are well illustrated by the experience of a dairy in Kansasville, Wis. Before shooting, the output of the deep well turbine pump was 119 hp. Assuming a wire-to-water efficiency of 75 per cent and a power cost of 0.77 cents per kwhr. in this case, the cost per hundred gallons would have been 0.524 cents. After shooting, the output horsepower was 115.5, so that, on the same basis, the cost per hundred gallons would be 0.462 cents, a saving of 0.062 cents. Such an amount may seem negligible, but it must be remembered that if the pump were operated continuously for one year after dynamiting, this saving would amount to $1,042. With an 85-per cent utilization factor, i.e., with the pump in operation 310 days of the year, the saving would amount to $900. In other words, dynamiting increased the capacity of the well 4 per cent and resulted in a saving of $900 for every subsequent year of operation, representing a 45-per cent dividend each year on the investment of $2,000.

Another deep well, in Lomira, Wis., was dynamited by the same contractor. There, the capacity was increased 46 per cent through the dis-

charge of five 10-lb. and two 25-lb. shots in the St. Peter and Dresbach sandstones. The well had a 16-in. top and an 8-in. bottom diameter to a depth of 1,195 ft. In this case, the reduced pumping costs, resulting from the great increase in specific capacity, made possible savings large enough to pay for the cost of dynamiting within a few months of operation.

Discussion by ***A. P. Kuranz.**** From the experiences noted in Mr. Milaeger's paper it seems quite logical to conclude that dynamiting of wells to improve their flow has proved an effective procedure. Since Wisconsin and Illinois water wells have been subjected to this method of flow improvement more than those of any other section of the country, a great necessity for further research and careful record-keeping by water works men of that area seems indicated. Perhaps the most valuable contribution the writer can make to this subject, then, is to outline his experiences in shooting deep wells at Waukesha, Wis.

Until 1930, it was thought that the maximum depth at which water could be obtained in the strata at Waukesha was approximately 1,300 ft. At that time, however, the state geologist, on the basis of further analysis and experience, decided that water could be obtained from the deeper strata and, therefore, suggested deepening the wells to approximately 1,800 ft.

In following this suggestion, a 1,282-ft. well, cased through shale only and leaving exposed the upper lime rock from which considerable water was obtained, was deepened to 1,783 ft. In the process, the entire casing was removed, new casing substituted for the worn portions, and the entire shale and upper lime rock (360 ft.) cased off. A 12-in. pump capable of delivering 1,000 gpm. at a setting of 360 ft. was then installed and a 48-hr. continuous pumping test run.

Static level before pumping commenced was 112 ft. from the surface. After 48 hr. of continuous pumping, the water had dropped to a level of 288 ft., a drawdown of 176 ft. The production at the end of 48 hr. of pumping at this level was 1,060 gpm., i.e., a specific capacity of 6.02 gpm. per foot of drawdown.

Following this, the well was shot with four 125-lb. shots of 100-per cent dynamite, three shots being discharged in the lower 100 ft. of the well and one, approximately in the middle of the Mt. Simon sandstone stratum. After the well had been cleaned thoroughly, the same test pump was installed again and a 12-hr. continuous test conducted. Static level remained the same as before shooting (112 ft.), but the pumping level was raised 50 ft. On the other hand, at the end of the test, the pump was

* Supt., Water Dept., Waukesha, Wis.

producing 1,205 gpm., an increase of 145 gpm. With the decrease in drawdown, this raised specific capacity from 6.02 to 9.57 gpm. per foot of drawdown, an improvement of 59 per cent.

This work was done in 1932, but conditions now are practically the same and the well has been called upon to produce its full share of the load. The experience led the department to draw up specifications requiring the dynamiting of all new and rehabilitated wells before testing. It is felt that this procedure has considerably improved the supply in this locality.

This experience, as well as that reported by Mr. Milaeger, indicates clearly the value of records. Whether a well is shot or not depends upon local conditions, but the value of keeping a record of the location of waters in it cannot be overstressed. At Waukesha daily records of drawdown and production are being kept on all wells. These data are then summarized monthly and plotted on graph paper. After several years of gathering such information, it will be turned over to the state department of geology for further study. In this way it is hoped to make some contribution to the general information on the subject of well shooting and its relation to operating conditions.

Experiences in Developing Rock Wells

By J. A. Carr

AT FIRST thought, the idea of developing a rock well no doubt seems rather ridiculous. Until early in 1940, the author, too, was satisfied in the accuracy of that opinion. His experience since then, however, has convinced him that the yield of many rock wells, at least in the red sandstone formation of northern New Jersey, can definitely be increased by agitation.

Most engineers and well drillers have accepted the idea that the completion of drilling a rock well is the final step. They agree, of course, that the hole can be straightened or its diameter increased, but, at the same time, are certain that nothing can be done to increase the yield of such a well when it is less than anticipated or required.

A recent opinion on the yield of water wells is that there is little real problem of yield in rock wells, the matter being chiefly one of chance; while the yield in sand and gravel wells depends to great extent on the mechanics of development. From experience in Ridgewood, N.J., during the past two years, however, it appears that, in many instances, the odds in favor of increasing the yield of rock wells can be bettered by application of some of the principles of development that have heretofore been confined to the construction of sand and gravel wells.

Early in 1940, the contractor engaged to drill Ridgewood's Fairview St. Well had completed a well in lower New York State. Upon test, this well had shown a yield of 120 gpm. at a 200-ft. pumping level, which was less than had been anticipated and required. In seeking a solution to the problem, the contractor explained that though the well could be deepened or dynamited, it was his opinion that nothing was to be gained by drilling deeper and experience indicated that dynamiting in red sandstone was ineffective. He suggested, however, that if the well was in an unconsolidated formation its yield might be improved by agitation, though, admittedly, there was no precedent for the belief that agitation would increase the yield of a rock well. On the basis that no other solution seemed

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A paper presented on October 17, 1941, at the New Jersey Section Meeting, Atlantic City, N.J., by J. A. Carr, Supt., Water Dept., Ridgewood, N.J.

feasible, then, the owner ordered the contractor to proceed with such an attempt; whereupon the well was developed for several days with a conventional surge plunger of the type used in sand wells. Much to the surprise of all concerned, a retest after treatment showed a yield of 250 gpm., an increase of more than 100 per cent, at the same pumping level.

Shortly after this successful application of agitation, the Fairview St. well was completed. Upon test it showed a yield of 290 gpm. at a 150-ft. pumping level, but since this well was drilled in a similar formation, the contractor obtained permission to experiment further with the new development practice. The well had a 16-in. outer casing to rock and a 12-in. inner casing cemented 22 ft. into rock, the inner casing extending to a depth of 62 ft. Agitation was started with the same type of surge plunger used in the previous work. During the development many cubic feet of sand, clay and pieces of rock were bailed out of the well; and, after five days, small pieces of cement were discovered in the bailings. It was feared then that the seal might be damaged by further development, so agitation was discontinued and the well again tested. On this test the well yielded 370 gpm. at the same pumping level, an increase of almost 28 per cent.

Application of Agitation Technique

Some years previous to this experience, the Ridgewood Water Dept. had constructed a well known as Wortendyke No. 8, which had yielded only 60 gpm. at a 140-ft. pumping level, because of which low capacity no pump had been installed. This well also had a 16-in. casing to rock and a 12-in. casing cemented 30 ft. into rock, the inner casing extending to a depth of 56 ft. Following the two successful experiments with agitation, this well, too, was developed in a similar manner for about 10 days, at the end of which a test showed a yield of 225 gpm. at the same drawdown. Although no cement had been discovered during bailing in this case, chemical analyses and other tests indicated that the seal had been broken.

From these experiences it was apparent that most of the action in the course of development was taking place immediately below the casing. Therefore, rather than destroy the seal or attempt to protect it, it seemed proper to complete the development before placing the permanent seal. It seemed logical, also, to conclude that if the effects of the agitation could be spread over a greater area of the well, better results would be obtained. This theory, then, was tested in the next experiment.

Wortendyke No. 2 was an old single-cased well which it was decided to double-case and seal at a depth of 70 ft. A temporary seal was set at 70 ft. and the well tested, showing a yield of 80 gpm. at a pumping level of 200

ft. The temporary seal was then placed on the bottom of a string of 8-in. pipe, 200 ft. long, and development started. In this case a long heavy steel valve type of plunger was used in place of the conventional one. Development was continued for 20 days, 10 ft. of 8-in. pipe being removed each day until the packer was back at the original setting of 70 ft. The well was then retested and shown to yield 225 gpm. at the same pumping level, an increase of 180 per cent.

In August 1941, the department completed Hartung No. 2 Well, constructed in the same manner as Wortendyke No. 2. It also was first tested with a temporary seal at the location of the permanent seal and then developed with the temporary seal on the bottom of a string of 8-in. pipe. Before development the well yielded 70 gpm. at a 200-ft. pumping level, and after 16 days of agitation yielded 175 gpm. at the same level, an increase of 150 per cent.

During development of all these wells, the holes were bailed frequently, and in every case it was found that a considerable amount of clay, sand and pieces of rock was dislodged and settled to the bottom. In the last instance, Hartung No. 2, approximately 2 cu.yd. of material were removed during agitation.

Theory of Development

From the results obtained in these experiments, the author is convinced that the yield from rock wells in the North Jersey red sandstone can be increased by development. The explanation of this increase in yield, however, can only be one of opinion.

It is common knowledge that in one method of well construction in unconsolidated formations, mud or clay is pumped in to build up a well wall, and, after the well is completed, the mud must be removed from the portions of the well from which water is to be drawn. On the other hand, in drilling through sandstone there are encountered numerous layers of shale, which, when drilled, form a heavy gummy clay. Many times when the bit is withdrawn, the clay is found to be on top, in the watercourses and above the wearing surface of the bit, adhering so firmly that it must be chopped off. Since the bit is, or should be, dressed out to the full required diameter of the well being drilled, the vertical oscillation and the frequent withdrawals of the bit plaster the clay solidly into all the small cracks and crevices of the rock, unavoidably forming a clay seal which prevents water from entering the well freely. It is that clay seal which is broken down and removed by agitation.

Judging from the amount of sand also dislodged, it may further be supposed that, even with no clay present, the removal of the loose sand, which

probably tends to clog the interstices of the rock and impede the normal flow of water, will increase the capacity of the well.

On its newest well, Hartung No. 6, the department applied the cleaning and developing process even more thoroughly than in previous cases. First, the entire well wall was thoroughly scrubbed, using a steel brush with $\frac{1}{4}$-in. bristles, $12\frac{1}{2}$ in. in diameter, i.e., $\frac{1}{2}$ in. greater than the diameter of the well. This brush, designed and constructed by the contractor, was passed up and down through the well several times and a considerable quantity of clay and loose rock removed.

With the idea of spreading the effects of agitation still further, the contractor also made a double seal—a steel cage-like structure, 20 ft. long, with a temporary seal at top and bottom. The whole cage was suspended on a string of 8-in. pipe and lowered 450 ft. to the bottom of the well and agitation started. With this device, the effects of agitation are almost wholly confined to the 20 ft. of well wall exposed between the seals. The assembly was raised 20 ft. at a time, at intervals of from $\frac{1}{2}$ to 2 days. Tests before and after development showed yields of 150 and 240 gpm., respectively, at the same pumping level.

In closing, the author would like to profess his belief that the treatment methods described here are applicable to other types of consolidated formation, and that their demonstrated success in the North Jersey area should prompt further experimentation in other areas.

Treating Well Screens With Acid

By John Barth

THE city of La Crosse, Wis., draws its main water supply from 24 ten-inch wells, grouped in six squares and spaced 100 ft. apart within each square. A low-lift pumphouse in the center of each square picks up the water through horizontal suction lines and delivers it to a low-pressure reservoir of 1-mil.gal. capacity. The wells are located in a marsh which is subject to flooding by the overflow of the La Crosse River, as well as by the high water of the Mississippi River, about ½ mi. downstream.

La Crosse is located on a large sand bar formed by the junction of three rivers—the Mississippi, the Black and the La Crosse. Its underground formation is typical of a sand bar, the sand ranging from fines to coarse gravel in various layers, with the best gravel and water-bearing sand directly above the sand rock. The wells range from 108 to 135 ft. deep, averaging 125 ft., and have a screen length of 26 ft. When they were put into operation, drawdown, or vacuum, as shown by the gages, was from 11 to 14 in., each well giving a different reading, varying with the character of the sand and the height of water in the Mississippi.

The wells were put into operation on December 16, 1913, and, as water was drawn from them, vacuum increased to 22–24 in. in five years. To combat this rise, it was decided to surge the wells by attaching a washer to the tools of a drilling machine to force the water back and forth through the screen; and then pump the wells to waste. This procedure reduced the vacuum to 16–17 in., decreasing it each time the wells were surged, but never reaching the original value because of the incrustation that could not be removed by surging.

In 1927, thirteen years after the commencement of operation, it was decided to pull the well screens and clean them above the ground, using muriatic acid to remove the incrustation. A contract was let to a well driller to clean those showing the highest vacuum. Because he was not

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familiar with the work, however, the driller succeeded in getting out only four of the screens, the remaining ones being broken and taken out in pieces.

In the following year, the Board of Public Works entered into an agreement with another well driller to remove the other screens. By a system of wooden blocks, he managed to pull them all, but some were in such poor condition that they disintegrated as soon as they had dried. The corrosive agent involved was carbon dioxide gas, which had attacked the zinc in the red brass of which the screens were constructed. To counteract this attack "Everdur" metal screens were used for replacements. With these screens vacuum could not be brought back to the original 11–14 in., but was reduced to 16–17 in.

At this juncture, the possibility of sinking wells at a new location was taken under advisement, the general opinion being that, as the water was drawn to the well point, it carried with it fine sand that would eventually seal off all the water. The question became one of sinking new wells or treating the existing wells to remove the incrustation. After careful chemical analysis and study, it was decided to try acid treatment on eight of the wells.

Treatment Procedure

Since the wells were located away from the pumphouse and had a vertical opening, they were relatively easy to treat. The top flange was removed and the well pumped heavily, using compressed air for an air lift. This cleaned out all loose dirt and accumulation on the bottom. Sufficient "Dow metal" (a magnesium compound) to raise the temperature to 175°F. upon reaction with the acid was then placed in the well. The increase in temperature occasioned by this reaction aids the acid to take effect upon the incrustation.

The next step in the procedure was to put down a packer consisting of a wooden disc fitted with pieces of rubber belting. A hole was drilled through the center of the disc and a 2-in. pipe, perforated below the disc to allow the introduction of acid, was fastened firmly to the assembly. When treatment was started the packer prevented acid from rising above the position at which it was set, thus confining the acid reaction to the screens only.

In mixing the acid solution, a predetermined amount of water was first put into the mixing tank. An inhibitor (Laynite #a-13), to prevent the acid from destroying the wrought-iron casing and the screens, was then added. Concentrated acid in an amount to give a concentration of about 25 per cent, and, finally, a stabilizer, to keep the dissolved incrustation in

solution, completed the mixture, which was then agitated thoroughly for 20 min. by the use of compressed air.

Treatment was effected by pumping enough of the mixture to fill the screens down through the 2-in. pipe. The reaction of the acid on the "Dow metal" raised the temperature and the hot acid took effect on the incrustation. As shown by the pressure gage, the reaction of the acid on the incrusting material raised the pressure at the surface from 10 to 15 lb. This reaction was permitted to continue for 1 hr., at which time the remainder of the acid solution was reduced to a concentration of about 15 per cent, and pumped down to the screens. The weaker solution forced the original mixture out of the screen where it took effect on the incrustation on the sand surrounding it. This reaction raised pressure at the surface to about 40 lb., and at the bottom to about 90 lb.

When this latter reaction had continued for $\frac{1}{2}$ hr., clear water was pumped down the pipe, forcing all acid out of the screen into the adjacent sand, where it was allowed to react an additional $1\frac{1}{2}$ hr. The pressure was then released and the pipe and packer removed. Finally, the air compressor was used to pump the water in the well to waste, bringing up all loose material and acid. Pumping was continued until litmus paper tests showed that all acid had been removed from the well.

When these wells were put back on the system, after treatment, it was found that drawdown, or vacuum, had decreased from 25 in., in the worst case, to 11 in., and that one well which previously had produced no water with the air-lift, yielded as much as the others. For all the wells treated, yield was increased from an average of $1\frac{1}{4}$ to 2 mil.gal. per group of four wells, the best group producing 2.4 mil.gal. after treatment.

Eight wells were treated in March 1941, and, to date, neither volume of water pumped nor vacuum conditions have changed materially. According to the gage, vacuum conditions now are the same as when the wells were first put into service. On the basis of performance of the first wells treated, eight more were cleaned in August 1941. Costs, including the services of a chemist, two laborers and a truck, were about $200 per well for the first group, and, because of price rises, $240 for the second group.

Restoring Well Capacity With Chlorine

By E. D. Brown

THE city of Eau Claire, Wis., (1940 population, 30,517) is situated at the junction of the Chippewa and Eau Claire Rivers. It is the wholesale shipping center for the northwestern part of the state and has a large number of industries, the largest being the U.S. Rubber Company's Gillette plant, which is also the largest consumer of municipal water.

The original supply of well water was obtained from a series of wells located north of the city on the west bank of the Chippewa River. This supply had a high iron and manganese content, which, in time, caused considerable trouble in the distribution system. It was decided, therefore, to investigate the possibility of obtaining a better source of supply.

After numerous test wells had been sunk, a very good supply, both in quality and quantity, was obtained from test wells located on the east bank of the Chippewa, about two miles north of the city. This field was developed in 1934 with the sinking of four wells, the supply being pumped into a reservoir at the field and delivered by gravity from there to the downtown pumping station.

Total capacity of these four wells was 7,090 gpm., which was adequate at the time they were put into service. Because of the rapid increase of consumption in the following years (see Table 1), however, two new wells were required by the fall of 1936. These additional wells were ready for service in the summer of 1937.

At about the same time as the need for the additional wells was taken under consideration, a drop in capacity in the four original wells was noted; and by the fall of 1938 the problem had become so serious (see Table 2) that its quick solution was imperative.

In investigating the problem, it was remembered that, a short time after the wells were put into operation, a bacterial growth had developed in the well field reservoir and pipe lines, causing considerable difficulty. Working from this lead, responsibility for the well capacity reduction was

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traced to the same source, a growth of the same type having clogged the well screen and the sand and gravel formation around it, reducing the available area for water passage.

Treatment Procedure

Beginning in 1935, it had been standard practice to treat the well water with chloramines to overcome the growth in the reservoir and pipe lines. The effectiveness of this treatment, then, suggested its adaptation to the new problem. On this basis, the following procedure was developed:

TABLE 1

Annual Water Consumption, 1934–39

YEAR	CONSUMPTION, IN MIL.GAL.
1934	1,153
1935	1,341
1936	1,822
1937	2,071
1938	2,036
1939	2,475

TABLE 2

Capacities of Wells Before and After Treatment

DATE OF TEST	CAPACITY, IN GPM.			
	Well No. 1	Well No. 2	Well No. 3	Well No. 4
Start of Operation—October 1934	1,850	2,085	1,740	1,415
First Treatment—November 1938:				
Before	395	1,080	1,360	515
After	1,740	1,980	—*	1,400
Second Treatment—April 1940:				
Before	1,540	1,945	1,820	—
After	1,780	2,060	1,960	—*

* Not included in treatment.

A weighed amount of chlorine was applied to the discharge line from the well to be treated. The chlorine solution formed was then washed back into the well by the head held in the field reservoir. Only one well could be treated at one time as it was necessary to keep the others in operation to maintain service. For this reason, the amount of water used for backwash was not known, there being no provision for metering. Chlorine residuals were taken at definite intervals when the well was pumped. After treatment, the well was left idle for 24 hours, following which it was pumped to waste and the capacity measured.

DATE		CAPACITY, IN GPM.
Well No. 1		
10/11/34	Capacity tested	1,850
11/26/38	Capacity tested	395
12/ 5/38	30 lb. chlorine backwashed into well; well pumped to waste; residual excess, 11.0 ppm.; large amount of suspended material and algae in waste water	
12/ 9/38	Well pumped 6 hr.; capacity tested	1,470
12/12/38	30 lb. chlorine backwashed into well	
12/13/38	Well pumped 4 hr.; 10-min. pumping residual, 8.0 ppm.; 4-hr. pumping residual, 0.2 ppm.; capacity tested	1,590
	Well backwashed with full capacity; well pumped; suspended material much in evidence during pumping; capacity tested	1,660
12/14/38	Well backwashed with full capacity for 1 hr.; capacity tested	1,720
	Well pumped 2 hr.; capacity tested	1,680
	Well backwashed with full capacity for 2 hr.; capacity tested	1,720
	Well pumped 2 hr.; capacity tested	1,700
12/15/38	Well backwashed with full capacity for 4 hr., using 60 lb. chlorine	
12/16/38	Well pumped; residual 7.0 ppm.; capacity tested	1,740
12/17/38	Well put into service	
4/ 8/40	Capacity tested	1,540
	30 lb. chlorine backwashed into well	
Well No. 1—*Continued*		
4/ 9/40	Well pumped 2 hr.; residuals: Start.......0.0 ppm. 5 min......0.35 ppm. 15 min......0.5 ppm. 2 hr.......0.15 ppm.	
	Capacity tested	1,620
	Well backwashed and pumped; capacity then tested	1,700
4/10/40	30 lb. chlorine backwashed into well; well pumped; capacity then tested	1,720
4/11/40	60 lb. chlorine backwashed into well	
4/12/40	Well pumped; residuals 1.0–1.5 ppm.; capacity tested	1,780
4/17/40	Well put into service	
Well No. 2		
10/11/34	Capacity tested	2,085
12/30/37	Capacity tested	1,030
	Pump column lengthened 10 ft.	
4/ 3/38	Capacity tested	1,330
11/26/38	Capacity tested (this and previous tests made into Wells Reservoir; following tests made with 10 × 8-in. orifice discharging at top of ground)	1,080
1/12/39	Capacity tested	1,380
	30 lb. chlorine backwashed into well for 2 hr.	
1/13/39	Well pumped 4 hr.; residuals: Start........15 ppm. 10 min.......12 ppm. 1 hr......... 2 ppm.	
	Capacity tested	1,740

DATE		CAPACITY, IN GPM.
	Well No. 2—*Continued*	
1/16/39	Short period of backwashing; 30 lb. chlorine then backwashed into well; capacity tested	1,860
1/17/39	Well pumped 2 hr.; residuals:	
	Start........18 ppm.	
	10 min.......17 ppm.	
	1 hr......... 1 ppm.	
	Capacity tested	1,930
1/18/39	30 lb. chlorine backwashed into well for 1 hr.	
1/19/39	Well pumped after backwashing chlorine; residuals:	
	Start........17 ppm	
	5 min.......19 ppm.	
	10 min.......18 ppm.	
	1 hr......... 2 ppm.	
	Capacity tested	1,940
1/21/39	Well pumped after backwashing; residual	
	Start.......0.0 ppm.	
	10 min......3.75 ppm.	
	Capacity tested	1,960
	30 lb. chlorine backwashed into well, using less water than heretofore	
1/24/39	Well pumped after backwashing chlorine; residuals:	
	Start.......22.0 ppm.	
	10 min...... 8.5 ppm.	
	1 hr....... 3.0 ppm.	
	Capacity tested; showed slow increase to	1,960
1/25/39	Well put into service	
4/18/40	Capacity tested	1,945
	30 lb. chlorine backwashed into well for 2 hr.	
4/19/40	Well pumped; capacity tested	1,980

DATE		CAPACITY, IN GPM.
	Well No. 2—*Continued*	
4/22/40	60 lb. chlorine backwashed into well; residuals:	
	Start..... 10 ppm.	
	5 min.... 10 ppm.	
	15 min.... 8 ppm.	
	30 min.... 4 ppm.	
	45 min..... 1.5 ppm.	
	Capacity tested	2,000
4/29/40	Well put into service; capacity tested	2,050
	Well No. 3	
10/11/34	Capacity tested	1,740
11/26/38	Capacity tested into reservoir	1,360
1/ 6/39	Capacity tested with 10 × 8-in. orifice	1,860
4/30/40	Capacity tested	1,820
	30 lb. chlorine backwashed into well	
5/ 1/40	Well pumped after backwashing; capacity then tested	1,830
	Residuals:	
	Start..... 7.5 ppm.	
	5 min... 10.0 ppm.	
	15 min... 11.0 ppm.	
	25 min... 8.0 ppm.	
	35 min... 6.0 ppm.	
	Capacity tested	1,900
5/ 2/40	40 lb. chlorine backwashed into well for 4 hr.	
5/ 3/40	Well pumped after backwashing chlorine; residuals:	
	Start...... 6.0 ppm.	
	5 min..... 9.0 ppm.	
	15 min..... 6.5 ppm.	
	25 min..... 6.0 ppm.	
	35 min..... 3.5 ppm.	
	2 hr....... 1.5 ppm.	
	Capacity tested	1,960

Logs of Wells—Concluded

DATE		CAPACITY, IN GPM.
Well No. 4		
10/11/34	Capacity tested	1,415
11/26/38	Capacity tested into reservoir	515
2/ 2/39	30 lb. chlorine backwashed into well	
2/ 3/39	Well pumped after backwashing chlorine; residuals: Start..... 2.0 ppm. 2 min.... 10.0 ppm. 10 min.... 15.0 ppm. 1 hr...... 1.5 ppm.	
	Capacity tested	1,380
Well No. 4—*Continued*		
2/ 6/39	30 lb. chlorine backwashed into well	
2/ 7/39	Well pumped after back washing chlorine; residuals: Start..... 3.0 ppm. 2 min.... 10.0 ppm. 10 min.... 17.0 ppm. 1 hr...... 2.0 ppm.	
	Many algae discharged after frequent surging for short periods	
	Capacity tested	1,400

The results of two separate treatments by this method are shown in Table 2, and the details of application for each well, in the accompanying tabulation of the well logs. That the procedure is both an effective and economical technique for reclaiming the well capacity is clearly demonstrated. It is the author's intention, however, to continue the annual experiments on the Eau Claire wells in an effort to discover new methods of application that will improve both the chemical and the mechanical procedure now used.

Water Softening Plant for Kansas City

By Melvin P. Hatcher

PRIOR to 1928 the city of Kansas City, Mo., was served with Missouri River water treated only by plain sedimentation after coagulation and followed by chlorination. In 1928 the city completed a new water purification plant of the conventional settling basin and rapid sand filter type (Fig. 1), having a nominal capacity of about 100 mgd. Today the city is adding facilities to this plant which will provide for a reduction in the hardness of the treated water from about 215 to 90 ppm. Barring too much delay in the delivery of materials,* the plant should be ready for operation in May or June 1942.

Water softening has a popular appeal in Kansas City. The idea has been approved by the voters several times, but for one reason or another the plan was never carried out. Water softening had its last approval at the polls in 1931 as a part of a so-called "Ten-Year Plan"; of a $32,000,000 bond issue for the plan, $550,000 was earmarked for softening improvements. The mandate of the voters was not carried out in this instance, mainly, it appears, because of the increase in operating cost that would result from softening. The people were informed that the operating costs could be provided for only by an increase in rates.

In 1940 the administration of the affairs of the Water Dept. was changed to an extent that permitted large savings in operating expenses, mainly through a reduction of about 30 per cent in operating personnel. The water softening improvements now under contract, costing nearly $900,000, are being constructed out of Water Dept. revenue and the additional operating expense of $150,000 to $200,000 per year will be borne by the Water Dept. without an increase in rates.

A paper presented on October 22, 1941, at the Missouri Valley Section Meeting, Cedar Rapids, Iowa, and revised as of March 24, 1942, by Melvin P. Hatcher, Chief Engr. and Supt., Water Dept., Kansas City, Mo.

* Having obtained an A-10 Project Rating in December 1941, and having overcome certain delays despite this low rating, it still appears (March 24) that softening will be started in May or June.

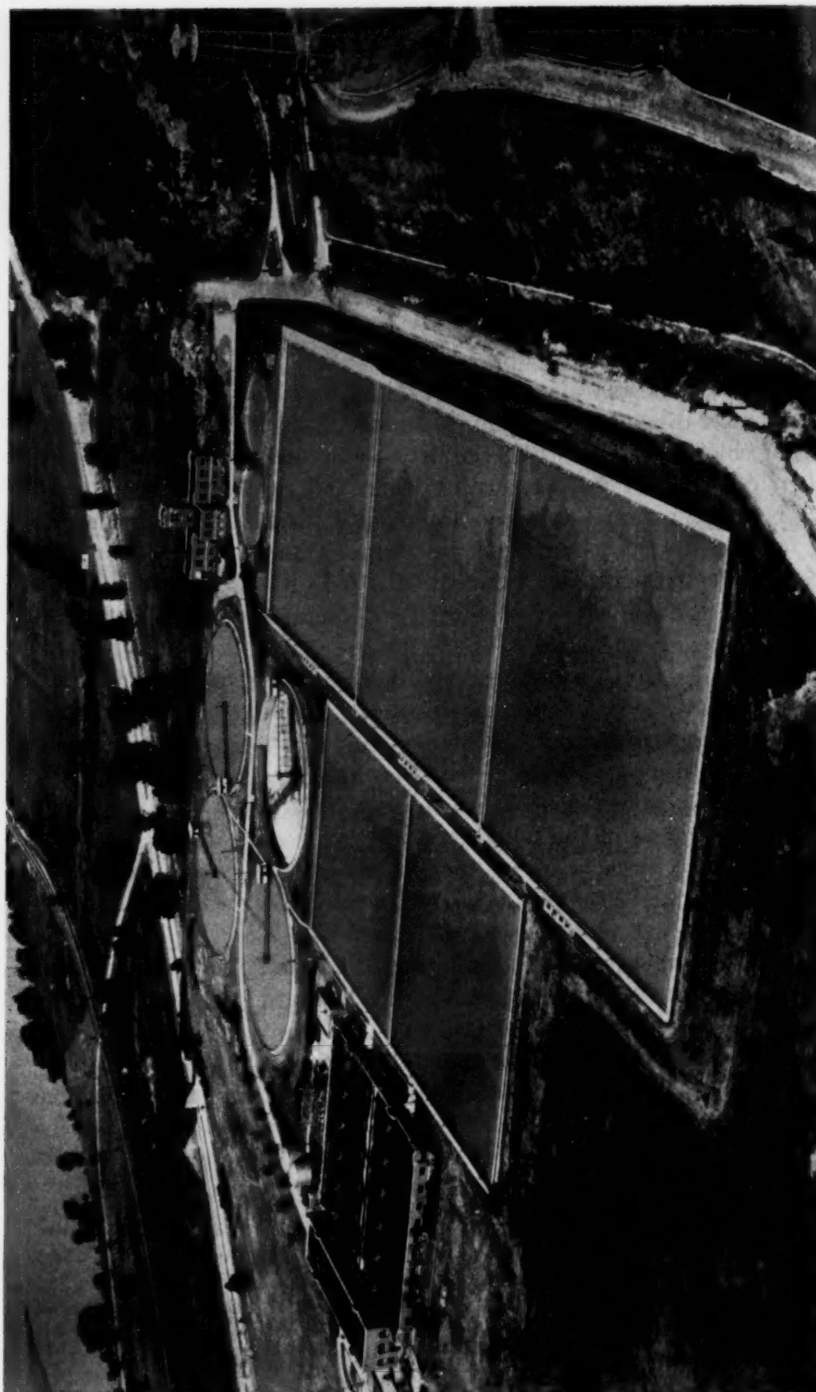

FIG. 1. Aerial View of Treatment Plant Before Construction for Softening—*Photograph by Fairchild Aerial Surveys Inc. for The Dorr Co., Inc.*

Missouri River water has an average hardness of about 215 ppm., of which about 155 ppm. is carbonate hardness. Turbidity averages about 2,500 ppm., with a maximum running as high as 15,000 to 20,000 ppm., of which a large portion is heavy suspended matter readily removable by settling without the aid of coagulation. Color is negligible.

To treat water with these characteristics, the present treatment plant provides for sedimentation, without coagulation, in circular basins pro-

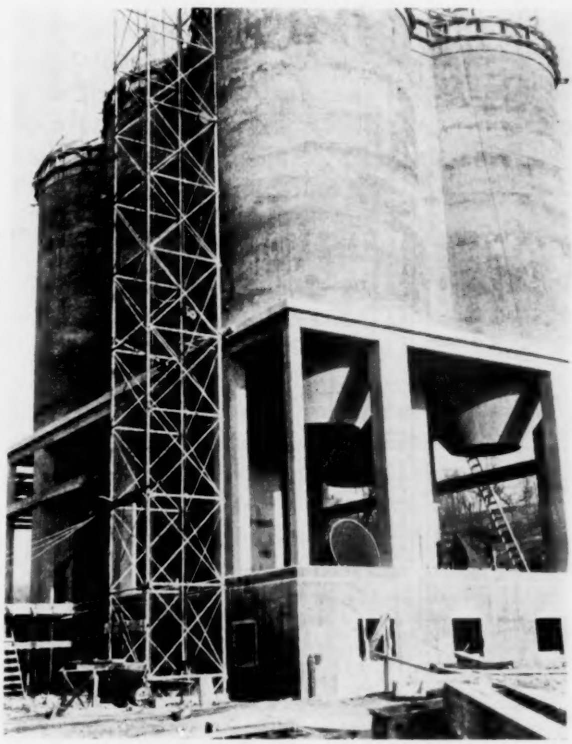

FIG. 2. Progress of Construction on Chemical Building, February 20, 1942—dry feed machines will be located on floor exposed, which will be brick-enclosed; chlorine room is located on floor below

vided with clarifier mechanisms followed by spiral-inward-flow mixing tanks, coagulation basins in two sets, and rapid sand filters. The retention periods at the nominal rate of 100 mgd. are: plain settling basins with clarifiers, 4 hr.; mixing tanks, ½ hr.; primary coagulating basins, 9 hr.; secondary coagulating basins, 3½ hr.; and total retention, 17 hr.

In the present plan of treatment, lime and alum are being used as coagulants, cake alum being made for the plant from bauxite and sulfuric acid. In the proposed plan, lime and soda ash will be used for softening. Where

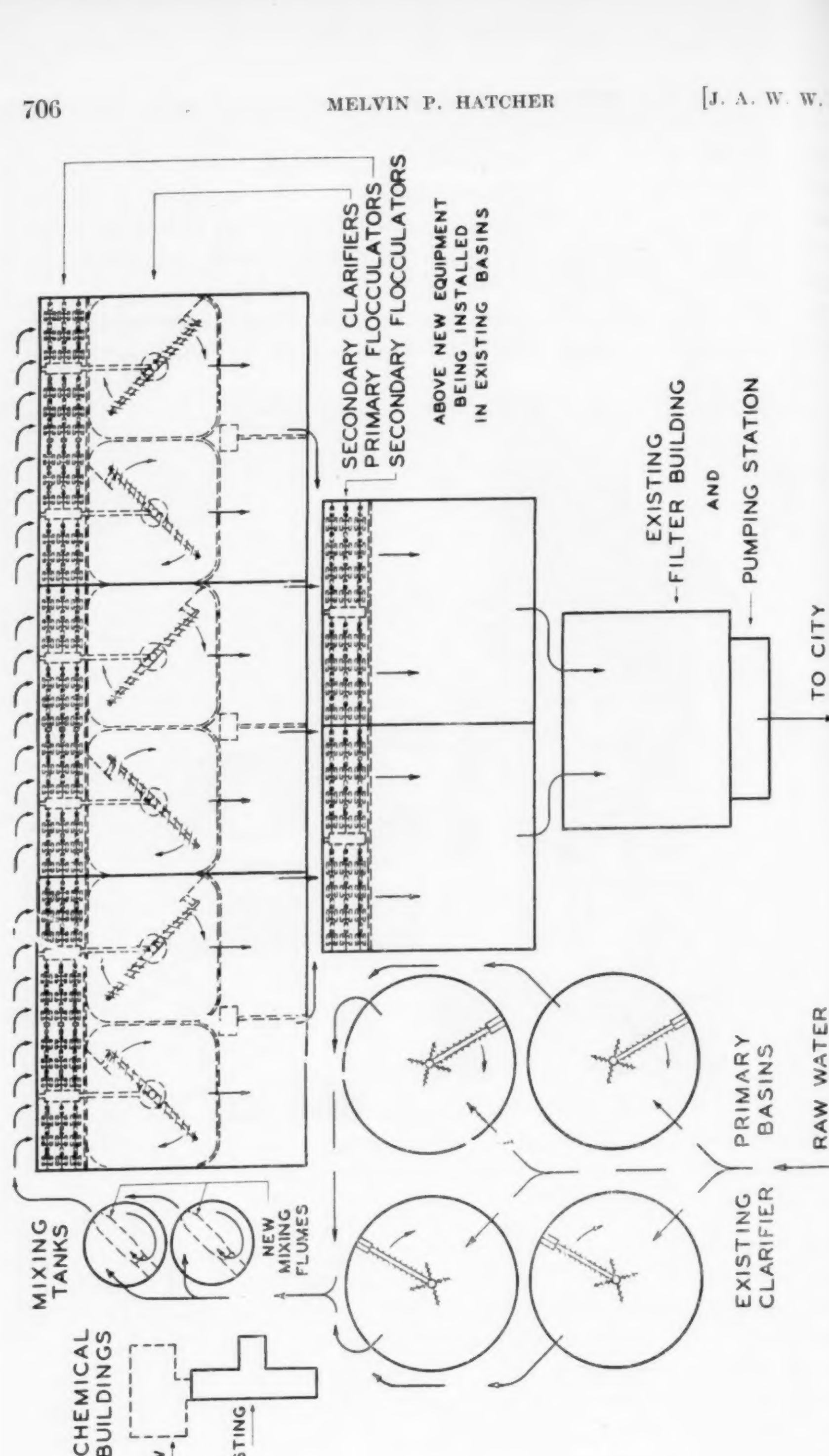

FIG. 3. Arrangement of New Equipment and Direction of Flow in Treatment Plant

about 400 lb. of coagulant per million gallons of water treated have been used for conventional treatment, softening will require the application of about 1,600 to 1,800 lb. of lime, soda ash and alum.

Chemical Handling Facilities

The contemplated use of this greater volume of chemicals will require more storage capacity and better chemical handling and feeding facilities than have been available in the present chemical building. An important unit in the improvements now being made, therefore, is a new chemical storage and handling building, costing about $250,000. All facilities, except those for the manufacture of alum, will be housed in this new unit.

The new building consists mainly of six cylindrical storage bins, 20 ft. in diameter and about 45 ft. high, from which the chemicals will be fed by gravity to four dry feed machines for alum or soda ash and four dry feed machines with slakers for lime. Each bin has a storage capacity of about 12,100 cu.ft., which volume will hold 300 tons of alum, 330 tons of lime, or 390 tons of soda ash. Under conditions of maximum chemical demand for treatment at maximum plant capacity, the bins will hold about ten days' to two weeks' supply of chemicals. Lime for softening is available from several kilns in Missouri, about one or two days' freight travel time from Kansas City. Chemicals will be delivered to the plant in hopper-bottom cars, discharged into hoppers below a shed-covered track and transported from these hoppers to the feed bins for the continuous chain bucket elevators.

The provisions for chlorine handling, storage and application have been planned on a large scale in anticipation of the probable use of break-point chlorination as a necessary part of the treatment process. The chlorine room provides space for storing 40 to 50 one-ton chlorine containers. Provisions for handling include a hoist for unloading containers from railroad cars and an overhead trolley system for handling the containers in the storeroom. An exhaust fan has been provided as a safeguard against the accumulation of chlorine gas resulting from the leakage from the containers in the storeroom. Rubber-lined pipe is used to convey the chlorine from two chlorinators to the several points of application.

Selection of Type of Softening

All the studies of softening plans indicated that there was no need for additional basin capacity since existing coagulating basins offered a 12.5-hr. retention period at the nominal plant rate of 100 mgd. Therefore, the problem of providing for softening was mainly one of deciding on the best possible arrangement of equipment in the present basins to provide for longer and better mixing of chemicals and for the concentration and removal of the lime sludge resulting from softening.

In the studies preliminary to the development of the present plans, consideration was given not only to the flocculator-clarifier type equipment which was finally chosen, and to a number of different arrangements of this type of equipment in the different basins, but also to the sludge blanket type of mixing and clarification equipment. Rather complete studies, including layout drawings and estimates, of both types of equipment indi-

FIG. 4. Progress of Reconstruction of Basins—(*Top*) General View, February 10, 1942; (*Bottom*) Installation of Clarifier Pedestals, March 3, 1942

cated that the most satisfactory and economical arrangement was to include flocculators and clarifiers built into the present primary basins and flocculators in the secondary basins in the manner shown in Figs. 3 and 4. The advantage of an accelerated reaction and a shortened retention period which is claimed for sludge blanket equipment was subject to some discount in this case because basin capacity was already available.

Consideration was given also to the lime-zeolite plan of softening as

opposed to the lime-soda ash plan. Although it appeared that there would be some saving in operating expense in the lime-zeolite plan, the saving was not enough to outweigh the rather considerable investment required in zeolite plant and equipment.

Summary of Improvements

In summary, then, the improvements for softening include a new chemical storage and application building, flocculation and clarifier equipment in the existing basins, and chemical handling, chemical application and

FIG. 5. Progress on Construction of Hydraulic Jump Mixing Flume Across Old Mixing Tank, February 20, 1942

sludge removing equipment. The extent and arrangement of present basins and conditioning facilities, as well as the location of the new mixing, flocculation and clarifier equipment are shown in Fig. 3. It should be noted, too, that the path of flow of the water through the treatment works will remain practically unchanged.

Of considerable importance is the fact that the improved conditioning of the water in the basins resulting from lime treatment will permit an increase in the rating of filters from 2 to 3 gpm. per sq.ft. This re-rating of filters will enable the plant to treat and filter about 150 mgd., an increase of 50 per cent in the nominal capacity of the works. Some of this increased

capacity is needed now since the present capacity of the plant has been reached on days of maximum demand. In other words, except for the additional pumping equipment needed, the treatment plant capacity has

TABLE 1

Sequence of Treatment and Retention Periods of Various Units at 100- and 150-mgd. Rates

TREATMENT UNIT	RETENTION TIME, IN HR.	
	At 100-mgd. Rate	At 150-mgd. Rate
Primary Clarifier Basins	4.00	2.67
Chlorination Contact Tanks	0.50	0.33
Mixing Flumes	—	—
Primary Flocculators	1.60	1.04
Secondary Clarifiers	4.52	3.03
Plain Sedimentation Basins	2.88	1.93
Secondary Flocculators	0.83	0.55
Plain Sedimentation Basins	2.67	1.78
Totals	17.00	11.33

TABLE 2

Summary of Expenses for Softening

ITEM		COST
Lime	16,200 tons @ $9.05	$146,610
Soda ash	1,650 tons @ 24.30	40,095
Alum	1,600 tons @ 16.30	26,080
Carbon dioxide*		5,705
Ammonium sulfate		2,200
Chlorine		4,200
Power		9,310
Operating labor and miscellaneous expense		65,800
Total softening expense		$300,000
Comparable expense before softening		121,500
Net softening expense		$178,500

* Though provided for in this estimate of added operating expense, it is not now planned to employ recarbonation unless operating results indicate a need for it. Recarbonation chambers have been constructed, but the equipment has not as yet been provided.

been increased by 50 mgd., and this capacity, if and when it is needed, is in itself worth about as much as the total cost of softening improvements. Quick mixing for the softening plant will be accomplished in two hy-

draulic jump flumes set atop the present spiral-inward-flow mixing tanks (Fig. 5). Incoming raw water will pass through the mixing tanks before flowing into the mixing flumes. This arrangement will provide for continued pre-chlorination; the old mixing tanks will provide a contact period for the chlorine at a lower pH than is available at any subsequent point in the treatment.

Costs and Savings

The sequence of treatment and the retention period of the various treatment units for both the 100- and the 150-mgd. plant rates, as arranged by the new softening plant, are shown in Table 1. The added expense of softening, not including fixed charges on the improvements now being made, is estimated at about $178,500 per year based on the treatment of 23,014 mil.gal. per year. In Table 2 is shown a summary of the figures supporting this estimate of added expense.

Against this added expense, the saving to the water consumer in decreased soap consumption is estimated conservatively at 87.5 cents per capita, or $350,000 per year. There will, of course, be other savings, such as lower maintenance on house plumbing and hot water heaters, lower industrial softening costs and less wear and tear on laundered fabrics.

Equipment and Engineering

The flocculator and clarifier equipment is being furnished by The Dorr Co., Inc., chemical feeding and lime slaking equipment by the Omega Machine Co., Kansas City, and the chemical transporting equipment by the Link-Belt Co. Construction work is being done by contract by S. Patti Constr. Co., Kansas City. A summary of all contracts follows:

Chemical Conveying Equipment (Link-Belt Co.)	$18,043
Chemical Feed Equipment (Omega Machine Co.)	19,497
Basin Equipment (The Dorr Co., Inc.)	196,000
Chemical Building	250,000
Settling Basins—Additions and Alterations	376,960
Structural Steel	8,303
Total Cost	$868,803

Preliminary plans for the improvements were made and reviewed by a board of engineers including representatives of the Black & Veatch and Burns & McDonnell engineering organizations, the Director of the Water Dept., Kenneth K. King, and the writer. Herbert O. Hartung, Chemist for the St. Louis County Water Co., was consulted in matters relating to the probable efficiencies of the several plans of treatment considered. Final plans for the improvement were prepared jointly by Black & Veatch, Cons. Engrs., and Burns & McDonnell Eng. Co., both of Kansas City.

Testing Small Meters in San Franciso

By George W. Pracy

THE proper operation of water meters as income-producing machines is still one of the problems of the water works operator. The problem is one that involves not only the mechanical repair of the meters, but also the determination of the proper policy under which they should be brought back to the shop for testing and repair.

Long before water meters were an accepted part of the water system, the need for some definite policy in this regard was recognized. As early as 1891, John Thomson, one of the early inventors and developers of the water meter, and Emil Kuichling (1) first raised the question in a paper read before the American Society of Civil Engineers. Since then, the problem has been studied and discussed by water works men, and many papers on the subject (2–13) have been published.

It is the author's purpose in this paper to present some further information on the subject gained in his work at the San Francisco Water Department, in the hope that this may bring the field one step closer to an ultimate solution of the problem.

In the fall of 1927, the Spring Valley Water Co., the predecessor of the San Francisco Water Department, purchased and installed 300 $\frac{5}{8}$-in. meters, 100 each of three different makes. These meters, the lower cases of which were painted red to make them readily recognizable, were set in a then new residential district of higher than average consumption. All service men were instructed to bring these meters directly to the meter shop for immediate repair and replacement if any of them had to be removed from service. Of the 300, eight were replaced by larger meters and one was discontinued, the remaining 291 being kept in service until July 1941, when 150 of them, 50 of each make, were returned to the shop for inspection and test. These 150 meters had not been removed previously and so had been in continuous service for fourteen years.

A paper presented on October 23, 1941, at the California Section Meeting, Fresno, Calif., and revised April 9, 1942, by George W. Pracy, Supt., San Francisco Water Dept., San Francisco.

Maintenance Records

Maintenance records on the original 300 meters—omitting difficulties due to hot water or other causes not the fault of the meter itself—were as follows:

Make A: Of 92 meters, 22 were removed because of faults, 2 being repaired before the end of the first year, 2 in the second, 2 in the third, 3 in the sixth, 1 each in the seventh, eighth, ninth, tenth and twelfth, 3 each in the thirteenth and fourteenth and 2 in the fifteenth year. The 8 meters replaced by larger ones were of this make. As the pressure in the area involved is not great, the pressure loss through the meter was probably the deciding factor in the change.

Make B: Of 99 meters, 6 were removed because of faults, 1 being repaired in the second year, 1 in the third, 1 in the tenth, 2 in the twelfth and 1 in the fourteenth year. The discontinued meter was of this make.

Make C: Of 100 meters, none were returned because of faults.

Test Results

The 150 meters returned to the shop were tested at various rates of flow, 50 meters of the same make being tested at one time. Each meter was tested three times at each rate of flow, except at the $\frac{1}{4}$-gpm. rate, where makes A and B were tested only twice, and at the $\frac{1}{8}$-gpm. rate, where all meters were tested only once. Results of the various tests are given in Tables 1 and 2. No definite record of the amount of water that had passed through the meters in the fourteen-year period is available, but it is estimated to be approximately 250,000 cu.ft. The nutations per cubic foot varied from 300 to 350.

Cost of Repairs *vs.* Loss of Revenue

The meters were changed by one of the Department's regular two-men crews, consisting of a service man and a laborer, using a Ford truck. This crew was kept on the job continuously until all 150 meters were changed—seven working days and three hours. Costs included the service man's pay, at \$9.50 per day, the laborer's pay, at \$6.80 per day, and the charge for the truck, at \$1.20 per day. To this total was added 12 per cent of the labor costs as a charge to cover insurance, vacations, sick leave and retirement funds, making the total cost of changing approximately \$0.95, exclusive of a charge for supervision of approximately \$0.05.

The repairs* in the shop cost: for make B meters—labor, \$87.55, ma-

* The meters were all oil-enclosed gear train type. Make A meters have not been repaired.

TABLE 1

Results of Accuracy Tests on 150 Meters at High Flow Rates

PERCENTAGE ACCURACY	MAKE A METERS				MAKE B METERS				MAKE C METERS			
	Flow Rates in Gallons per Minute											
	7	3	2	1	7	3	2	1	7	3	2	1
107	22	23	19	5	—	—	—	—	—	4	—	—
106	—	—	—	—	—	—	—	—	—	—	—	—
105	18	23	19	11	6	3	5	25	1	46	1	3
104	—	—	—	—	—	—	—	2	—	—	—	—
103	—	—	—	—	—	—	—	8	1	—	—	—
102	56	34	44	12	4	2	2	40	1	64	3	1
101	8	11	7	2	1	1	—	24	2	24	—	—
100	16	25	33	26	14	12	23	26	27	12	3	3
99	5	6	2	14	43	54	61	7	45	—	4	2
98	8	6	1	18	43	60	42	9	58	—	26	41
97	3	6	—	5	15	12	13	2	14	—	43	45
96	—	2	—	1	3	2	—	—	1	—	18	13
95	—	1	1	3	3	—	1	—	—	—	35	24
94	—	—	1	2	2	—	—	—	—	—	6	8
93	—	—	1	3	6	1	—	—	—	—	9	6
92	—	—	3	3	7	—	—	—	—	—	—	4
91	—	5	4	4	3	—	—	—	—	—	2	—
90	—	—	1	7	—	—	—	2	—	—	—	—
Below 90	—	—	5	25	—	—	—	1	—	—	—	—
Dead	14	8	9	9	—	3	3	3	—	—	—	—
Total Tests	150	150	150	150	150	150	150	149*	150	150	150	150
Average All Meters, Including Dead	92.2	96.6	95.1	89.2	97.6	96.6	96.9	99.3	98.7	102.6	96.4	96.6
Average All Meters, Except Dead	101.0	101.8	101.2	94.9	97.6	98.6	98.9	101.4	98.7	102.6	96.4	96.6
Average All Meters, Including Dead, at All Rates	93.5				97.3				98.5			
Average All Meters, Except Dead, at All Rates	99.6				99.1				98.5			

* One meter read only twice.

terial, $18.69, a total of $106.24, or $2.12 per meter; and for make C meters —labor $30.60, material $2.12, a total of $32.72, or $0.66 per meter.

Adding the cost of changing, at $0.95 each, to this, the total cost per make B meter would be $3.07 and make C meter, $1.61.

Various cities and regulatory commissions have set up limits of time and of volume metered between regular inspection and overhaul of meters. In most cases the time limit is five years, though it ranges from one to ten; and the limits for volume metered range up to 150,000 cu.ft.

In analyzing the loss of revenue through under-registration, it must be remembered, of course, that all rate schedules based on the New England Water Works Association plan already include, in the service charge, an

TABLE 2

Results of Accuracy Tests on 150 Meters at Low Flow Rates

PERCENTAGE ACCURACY	MAKE A METERS		MAKE B METERS		MAKE C METERS	
	$\frac{1}{4}$ gpm.	$\frac{1}{8}$ gpm.	$\frac{1}{4}$ gpm.	$\frac{1}{8}$ gpm.	$\frac{1}{4}$ gpm.	$\frac{1}{8}$ gpm.
Over 100	—	—	4	—	55	20
100–91	1	—	38	—	49	8
90–81	9	—	23	—	15	5
80–71	8	—	10	3	10	2
70–61	3	1	3	9	3	1
60–51	1	—	10	7	6	6
50–41	8	—	2	8	4	2
40–31	1	—	1	5	1	2
30–21	4	1	1	4	4	1
20–11	7	—	1	3	—	—
10–1	14	3	—	8	—	—
Dead	44	45	7	3	3	3
Total Tests.....	100	50	100	50	150	50

Total A, B and C over 90% @ $\frac{1}{4}$ gpm. = 147 of 350 tests and 54 dead
Total A, B and C over 90% @ $\frac{1}{8}$ gpm. = 28 of 150 tests and 51 dead

allowance for flows too small to be registered by the meter. Several decisions, or assumptions, must, however, be made, first of which is that a meter of the quality of make A is not desirable and should be eliminated. The less than 600 of these meters now in the system will have to be watched closely and eliminated as soon as they cease to be profitable.

The average registration of makes A and B meters on tests at flows of 1 gpm. or higher was 98.4 per cent, and at a flow of $\frac{1}{4}$ gpm., 82.6 per cent. On the basis of the figures for percentage of water used at various rates given by Trentlage (14) and Kuranz (15), the overall registration through these meters (after fourteen years of continuous service) averaged 95.3 per cent. To set up a basis for comparison, it must be assumed that the

meters registered 100 per cent when they were installed and that the decrease in accuracy was proportional to the square of the time in service, reaching an average loss in registration of 4.7 per cent at the end of the fourteenth year.

During the last year San Francisco sold water of a value of $5,791,456, or roundly $5,800,000, through 128,000 meters. On this basis, the calculated loss in registration, loss in revenue and cost of maintaining the meters for periods ranging from five through eleven years is as given in Table 3, which indicates that between the eighth and ninth years the loss in revenue increases beyond the cost of maintaining the meters. It can then be assumed that eight or nine years is the economical period that meters can remain in service without attention. It is realized, of course, that the testing of 150 meters is not sufficient basis for making any absolute

TABLE 3

Comparison of Loss in Revenue Through, and Cost of Repairs of, Meters From Fifth Through Eleventh Years of Service

CHANGE PERIOD IN YEARS	AVERAGE PERCENTAGE LOSS IN REGISTRATION	LOSS IN REVENUE	COST TO CHANGE AND REPAIR METERS
5	0.200	$11,600	$51,200
6	0.288	16,704	42,600
7	0.378	21,924	36,900
8	0.512	29,696	32,000
9	0.648	37,584	28,400
10	0.800	46,400	25,600
11	0.968	56,144	23,300

statement, the object of this summary being only to set up some procedure that can be used for further study.

Experience at Glendale

Since the reading of this paper in October 1941, Peter Diederich, Supt., Water Light and Power Dept., Glendale, Calif., has sent the author a memorandum which includes the following information:

"The following table [Table 4] shows results of 'as found' tests on 540 $\frac{5}{8}$-in. meters removed for test. These meters average 16.9 yr. in service without field test or repair. All these meters have oil-enclosed gear trains.

"The averages of oil-enclosed gear train meters are: on full stream, 98.3 per cent; at 1-gpm. flow, 87.8 per cent; and at $\frac{1}{2}$-gpm. flow, 68.4 per cent.

"The remaining $\frac{5}{8}$-in. meters in the system (with wash type trains) were also removed for test. The following table [Table 5] shows results of 'as found' tests of 531 old $\frac{5}{8}$-in. meters with wash type trains. These meters averaged 20.4 yr. in service without repair.

TABLE 4

Results of Accuracy Tests on 540 Oil-Enclosed Gear Train Meters

PERCENTAGE ACCURACY	PERCENTAGE OF THE METERS IN ACCURACY RANGES AT THREE RATES OF FLOW		
	Approx. 15 gpm.	1 gpm.	¼ gpm.
103 to 102	1.7	9.0	0.3
102 to 101	5.7	9.6	0.3
101 to 100	24.4	18.7	2.5
100 to 99	25.7	7.4	2.7
99 to 98	19.0	2.2	4.4
98 to 97	9.6	7.0	5.1
97 to 96	4.4	5.5	4.0
96 to 95	2.2	2.9	1.8
95 to 94	1.3	3.7	5.3
94 to 93	0.4	2.7	3.0
93 to 92	0.4	2.0	4.8
92 to 91	0.5	1.3	3.1
91 to 90	0.4	3.1	5.6
Below 90	1.5	10.7	39.6
Dead	2.8	9.4	16.8
Total....................	100.0	100.0	100.0

TABLE 5

Results of Accuracy Tests on 531 Wash Type Train Meters

PERCENTAGE ACCURACY	PERCENTAGE OF THE METERS IN ACCURACY RANGES AT THREE RATES OF FLOW		
	Approx. 15 gpm.	1 gpm.	¼ gpm.
103 to 102	1.1	—	—
102 to 101	1.1	—	—
101 to 100	6.2	1.7	—
100 to 99	10.1	0.5	—
99 to 98	14.3	3.2	—
98 to 97	13.7	1.9	—
97 to 96	11.9	3.4	0.2
96 to 95	6.2	2.5	0.2
95 to 94	5.4	2.8	0.2
94 to 93	3.6	4.0	—
93 to 92	2.9	3.6	0.6
92 to 91	2.9	5.3	0.2
91 to 90	1.7	8.0	0.4
Below 90	10.6	40.5	51.6
Dead	8.3	22.6	46.7
Total....................	100.0	100.0	100.0

"The averages of wash type train meters are: on full stream, 94.8 per cent; at 1-gpm. flow, 66.3 per cent; and at $\frac{1}{2}$-gpm. flow, 27.8 per cent. No test was made on 44 of the meters which were dead.

"At the present time we have 21,865 meters in service, with all services metered."

Mr. Diederick's tests seem to substantiate the author's conclusions regarding the period between tests under the operating conditions which obtain in the urea. Studies of previous tests showed that they were made at rates of flow and under conditions that do not permit of comparison. It is suggested, therefore, that some standards for meter testing, that will permit detailed comparisons with future work, be set up.

The author wishes to express his appreciation for the assistance of George Bauer, Foreman of the Meter Shop of the San Francisco Water Department, who made all of the meter tests reported.

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Limnological Observations on San Francisco Reservoirs

By H. C. Medbery

AN ATTEMPT is made in this paper to show the physical, chemical and, to some extent, the biological changes which take place in San Francisco reservoirs during an annual cycle. Observations have been made during the past several years, and the data from the more recent records are used in the tables and graphs included. The factors discussed include temperature, pH, dissolved oxygen, mineral content and biological growths. Graphical methods are used to explain a typical annual cycle showing the variations with depth of pH, dissolved oxygen and temperature. An isotherm sketch of a vertical section of each of two reservoirs is shown for the period April to October 1941, and a heat budget is given for the major portion of the same year. Mean temperatures and air movement at or near these reservoirs are given to indicate which weather conditions effect the different stratification phenomena.

The data given are from observations on San Francisco's two largest storage reservoirs in the Bay Area:

Calaveras Reservoir has a capacity of 31.5 billion gallons and a maximum depth of about 150 ft. When the reservoir is full, surface area is 1,420 acres and average depth, 68 ft. The reservoir is about $3\frac{1}{3}$ mi. long and an average of $\frac{2}{3}$ mi. wide.

Lower Crystal Springs Reservoir is the largest and deepest reservoir on the peninsula, having a capacity of about 11.3 billion gallons (without flash boards set in spillway) and a maximum depth of about 120 ft. Surface area is about 620 acres and average depth, 52 ft. The reservoir is nearly 4 mi. long and an average of $\frac{1}{4}$ mi. wide. Ratio of length to width is about 16 to 1 as compared with 5 to 1 for Calaveras Reservoir.

Figure 1 gives plan views of both reservoirs, showing their division into theoretical sections. This partitioning made to aid in copper sulfate treatment is shown for the purpose of giving the locations of tests.

A paper presented on October 23, 1941, at the California Section Meeting, Fresno, Calif., by H. C. Medbery, Chief Water Purif. Engr., San Francisco Water Dept., Millbrae, Calif.

Test Methods

Samples were collected at various depths by lowering a standard siphon bottle arrangement, set in a weighted container, to the desired depth by the aid of a graduated cord. Water passes through two, 250-ml. bottles, filling two 1-l. bottles. With an $11\frac{1}{2}$-in. difference of head and using small-sized copper tubing for connections, about 1 min. is required to fill the 1-l. bottle. Any desired depth can be reached in 30 sec. or less, so that the small bottle can change water at least twice in this zone before the sample is brought up for test.

Immediate determinations of pH values were accomplished colorimetrically by the use of a Hellige comparator. Dissolved oxygen content was also measured immediately using the starch-iodide method. Temperatures were taken in place by lowering a maximum-minimum thermometer; and the remainder of the tests were made after the samples were taken to the laboratory. Air movement was measured by a Dozier contact-type three-cup anemometer wired to a separate totalizer and air temperatures were taken with a maximum-minimum thermometer.

Factors Controlling Temperature, Dissolved Oxygen and pH Changes

Thermal Stratification

Depth of water, air temperature, radiant energy and wind velocity are the principle factors governing the stratification of bodies of water. Of less importance are shape and size of lake, surrounding topography and length of wind sweep across the surface. Radiant energy and air temperatures are perhaps the most important of these factors as the vertical change of water temperatures is the criterion for the formation of the thermal zones. Practically all of the sun's radiant energy is absorbed and converted into heat in the top 15 ft. of water. The deeper strata must be warmed by mixing with the warmer surface water by the aid of wind movement. The velocity of wind necessary to mix these two strata is dependent upon the difference in temperature and the thickness of the two layers. The warmer water is always on top except when the surface water temperature is below 4°C., at which time the colder water is on top. This resistance to mixing which is due to the difference in specific gravity of the warm and colder water is known as the thermal resistance to mixture, or, sometimes, as stability. When the thermal resistance is high enough to prevent mixing by the winds of the locality, the reservoir is in a stable condition; and when the thermal resistance is low enough to enable the winds to start the water in vertical circulation, the reservoir is in an unstable condition.

The depth of the transition zone, which is the stratum of rapid change in water temperature with depth, is determined by degree of seasonal change in spring, radiant energy, wind velocity and length of wind sweep. A wind of given velocity is more effective in circulating the water vertically if it blows over a long distance of water surface. A marked seasonal rise in mean air temperatures and low wind velocities during the spring season tends to form a thermocline near the surface. Modification of these factors tends to form a transition zone at a greater depth. If the mean air temperature rises are too gradual and the wind velocities too high dur-

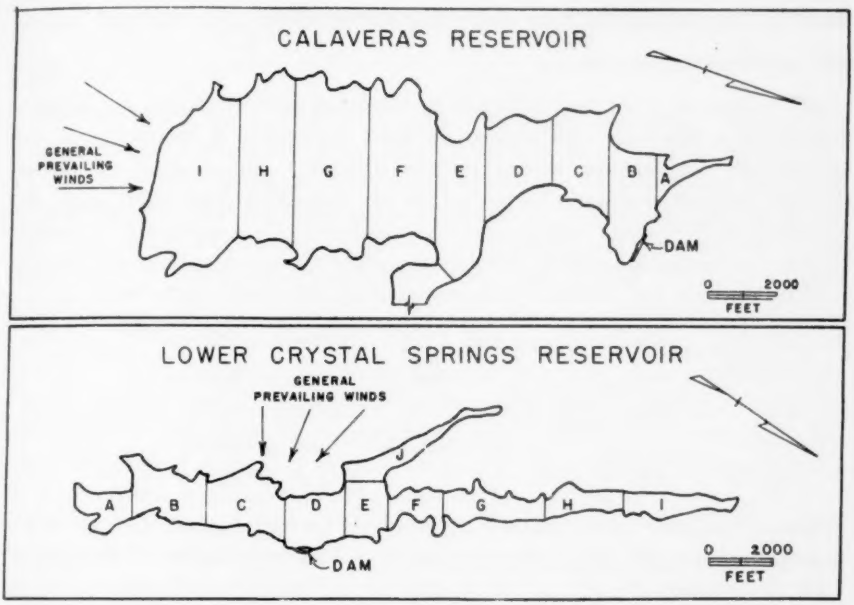

FIG. 1. Plan Views of Calaveras and Lower Crystal Springs Reservoirs; showing treatment sections

ing spring and summer, the reservoir may, if the depth is not great, be in complete circulation the year around.

Dissolved Oxygen

The dissolved oxygen in a reservoir is governed principally by three factors—plankton growths, bacterial action and vertical circulation. The respiration of the animal and fish life of reservoirs is of less importance. Algal growths usually increase the oxygen content of not more than the upper 15 ft. of water. Bacterial action is governed by the amount and

distribution of food supply, which is principally the dead plankton. The result is a depletion of dissolved oxygen in the immediate zone of bacterial activity. The depth position of these dead plankton is affected by all factors which govern the settling of particles. The vertical circulation is important in that all water undergoing circulation has a chance to keep its oxygen supply replenished by air at the surface. The speed of oxygen absorption is dependent upon wave action and saturation deficit, and, if bacterial action were high in the surface water, a lag phase in replenishment would develop, dependent upon the relative rates of depletion and absorption. The surface absorption affects only the water in the epilimnion, which is the circulation zone above the thermocline.

pH and Carbon Dioxide

pH is a measure of the hydrogen potential or free hydrogen ion concentration in a solution. Its change in reservoir water is indicative of the production or consumption of carbon dioxide. The change in carbon dioxide content necessary for a certain pH change is dependent upon the alkalinity of the water—the higher the alkalinity, the greater the necessary change in carbon dioxide to produce the same change in pH. The change follows the law for the first and second dissociation of carbonic acid, i.e.,

$$pH = pK_1 + \log \frac{HCO_3 \text{ (moles per liter)}}{H_2CO_3 \text{ (moles per liter)}}$$

$$pH = pK_2 + \log \frac{CO_3 \text{ (moles per liter)}}{HCO_3 \text{ (moles per liter)}}$$

$$pK_1 = 6.34 \qquad pK_2 = 10.22$$

When pH is below 8.3 a combination of HCO_3 and H_2CO_3 ($CO_2 + H_2O$) determines the pH and when it is above 8.3 a combination of HCO_3^- and $CO_3^=$ determines the pH. No appreciable amounts of $CO_3^=$ and CO_2 exist in the water at the same time.

When the pH of the surface water rises to 8.3 the algae are utilizing the free CO_2 in the water by the process of photosynthesis. As the free CO_2 is exhausted in waters having a pH above 8.3, the bicarbonate present is used as a source of carbon dioxide, the conversion being: $2HCO_3^- \rightarrow CO_2 + CO_3^= + H_2O$. This results in no change in the total alkalinity of the surface water unless the $CO_3^=$ and Ca^{++} content are high enough to precipitate and settle out, which is not the case in the reservoirs to be discussed. After the CO_2 in the surface water is below the point of equilibrium with the CO_2 in the air, there is, of course, a tendency towards absorption of CO_2, the extent of which is dependent upon the depletion of CO_2 in the water and the partial pressure of CO_2 in the air. The production of carbon dioxide which is evident in the transition zone and the hypolimnion is the

result of bacterial activity and the respiration of organisms not belonging to the plant kingdom.

Relation of Temperature, Dissolved Oxygen and pH to Annual Cycles

In Whipple's classification, both reservoirs studied would fall in Order 2 of "Tropical Lakes," showing one circulation season a year, beginning in December and lasting until spring. Instead of remaining at or near 4°C. the year around, however, bottom water temperatures range from 10° to 13°C. To give a better picture of the changes that take place in a reservoir, the dissolved oxygen content, pH and temperatures are plotted against depths for nearly all sampling dates for the year 1940.

Calaveras Reservoir

Figure 2 show the typical cycles for Calaveras Reservoir. The water is in complete circulation from late December until after early March. The temperature during this period is about 11° to 12°C. and dissolved oxygen content, about 85 per cent of saturation. By the last of March the upper strata are warming up, algae are utilizing CO_2, raising the pH of the surface water, but little change has taken place in the dissolved oxygen content. The next two weeks show a continued rise in surface temperature, a rise in surface dissolved oxygen and a definite stratification with respect to pH. Tests on May 17 show the thermocline to be well established for the season at about 20 to 30 ft. below the surface. The abrupt change in pH and the rapid drop in temperature at the 20–30-ft. depth, and the dissolved oxygen depletion in this zone, each of which is characteristic of the thermocline of this reservoir, are all evident at this time.

During June and July the temperature of the water in the epilimnion continues to rise slowly. The pH varies a little but remains high and the dissolved oxygen remains fairly constant. In the transition zone the dissolved oxygen content decreases to less than 1 ppm. In the hypolimnion, the zone below the thermocline, the temperature remains constant and the pH drops to 7.1 or 7.0 and stays there. The dissolved oxygen drops slowly and continues to do so until late November.

The temperature and pH decrease slightly in the upper zone of circulation during August and September and by October the transition zone begins to drop very slowly. By the end of October the thermocline lies at about 35 to 40 ft., and in early December it is at about 70 ft. Although the temperature is nearly constant throughout the reservoir at this time, the pH and dissolved oxygen content indicate that the reservoir is not in complete circulation until sometime in late December. All tests were made in section C (see Fig. 1), but the position of the thermocline is practically constant throughout the reservoir, as is shown by Fig. 3.

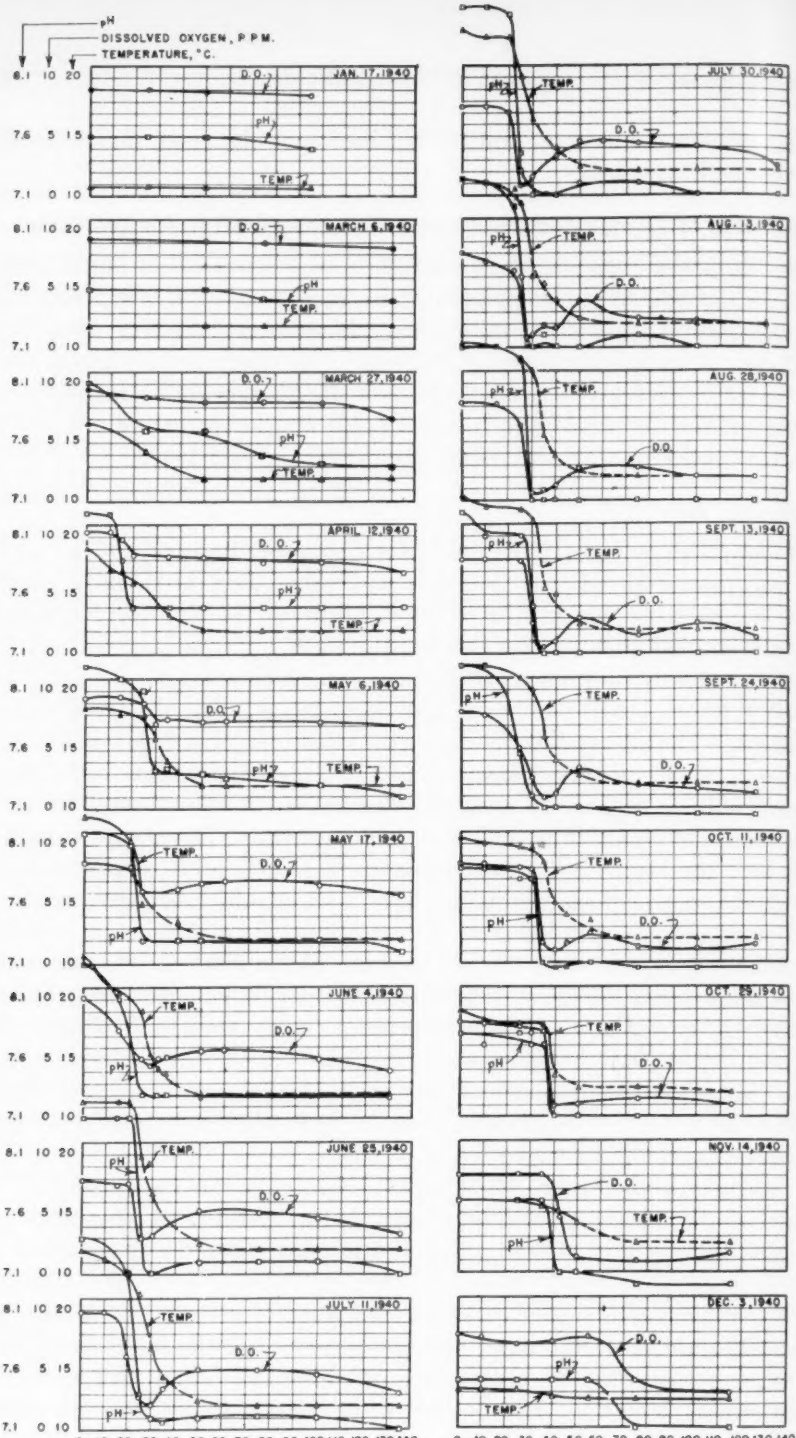

FIG. 2. 1940 Cycle of Temperature, Dissolved Oxygen and pH at Various Depths in Calaveras Reservoir

Lower Crystal Springs Reservoir

Figure 4 gives similar data for Lower Crystal Springs Reservoir. Because of different weather conditions, the period of vertical circulation in this reservoir, extends over a greater length of time. The temperature,

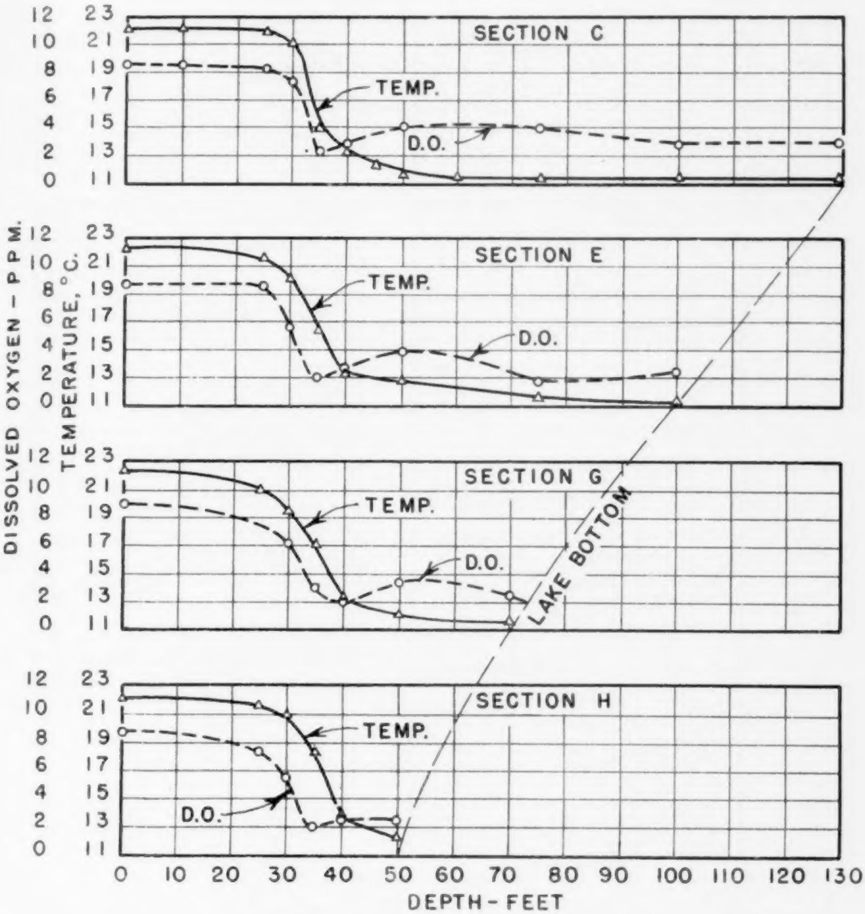

FIG. 3. Relationship of Temperature and Dissolved Oxygen to Depth for Various Sections in Calaveras Reservoir—September 10, 1941

dissolved oxygen and pH of the surface water are increasing during April and May. On June 7, the temperature and pH changes at the 50-ft. depth indicate the beginning of the formation of a thermocline. Marked stratification characteristics, however, do not occur until late August or

September. This is shown in the graph for September 11. On this date there are abrupt drops in pH, temperature and dissolved oxygen content at the 60-ft. depth, such as are shown for Calaveras during the middle of May at 20 ft. The transition zone has dropped to 65 ft. by October 31,

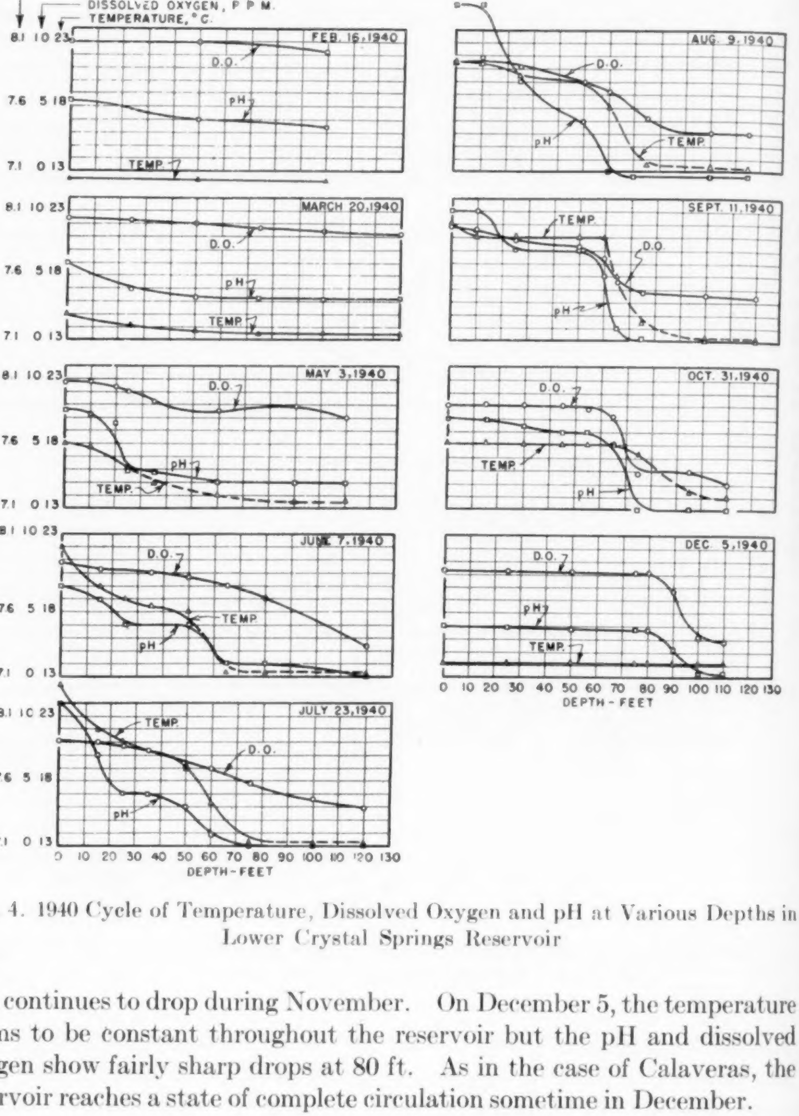

FIG. 4. 1940 Cycle of Temperature, Dissolved Oxygen and pH at Various Depths in Lower Crystal Springs Reservoir

and continues to drop during November. On December 5, the temperature seems to be constant throughout the reservoir but the pH and dissolved oxygen show fairly sharp drops at 80 ft. As in the case of Calaveras, the reservoir reaches a state of complete circulation sometime in December.

Yearly Variations in the Annual Cycles

The temperature, pH and dissolved oxygen cycles are quite consistent for Calaveras Reservoir year after year. The transition zone begins forming in April or May at about 15 or 20 ft. and usually drops to about 25 ft. and remains there throughout the summer. The water level in the reser-

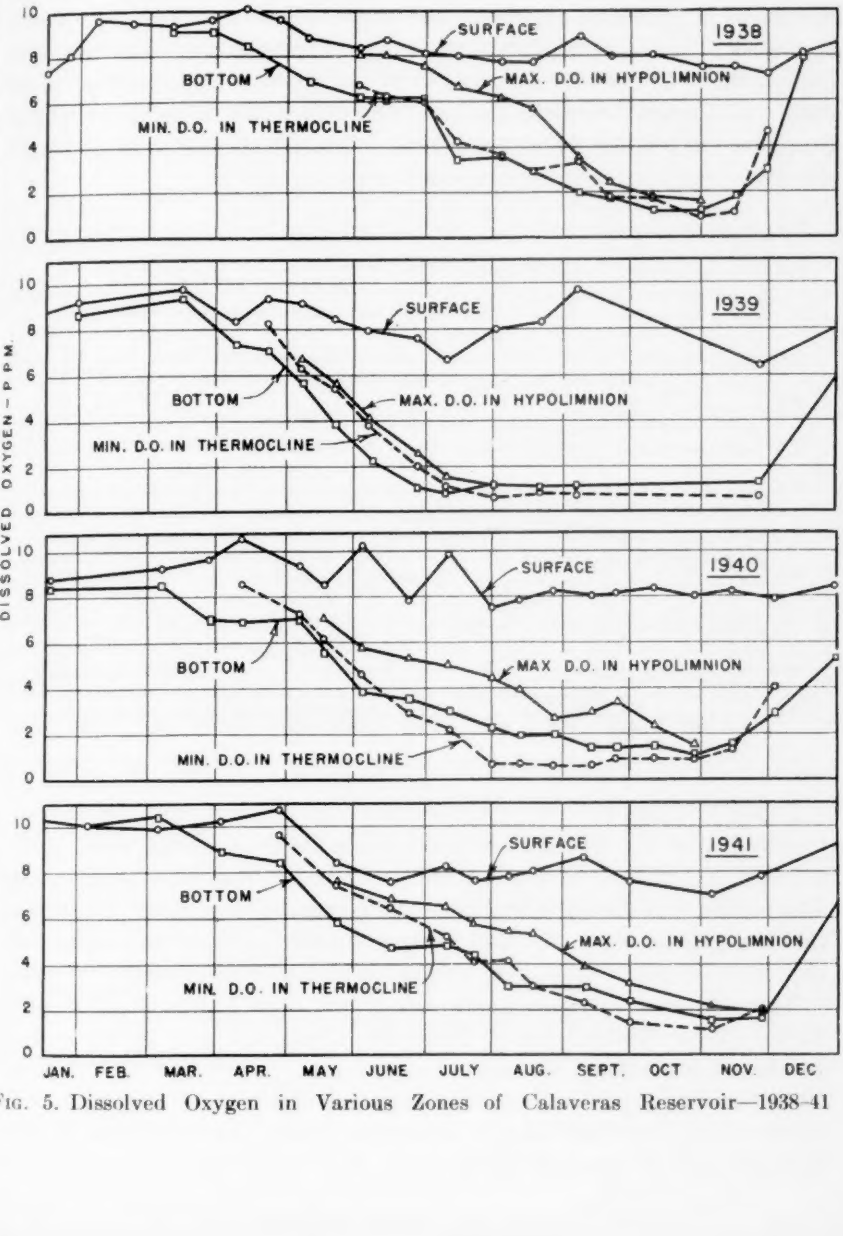

FIG. 5. Dissolved Oxygen in Various Zones of Calaveras Reservoir—1938–41

voir in different years seems to have little effect upon the depth of the thermocline. The thermocline begins dropping slowly in September or early October and continues to do so until the period of complete circulation beginning in December.

The dissolved oxygen is always high in the epilimnion, but there is some variation, dependent upon the algal population. Figure 5 shows the variations in dissolved oxygen in four depth zones for a four-year period. It should be noted that in 1939 the oxygen depletion was more complete. During this year the average water level was about 40 ft. lower than in the other three years. Since there was much less water in the hypolimnion, a smaller oxygen supply was available to supply the biochemical oxygen demand of an approximately constant algal population.

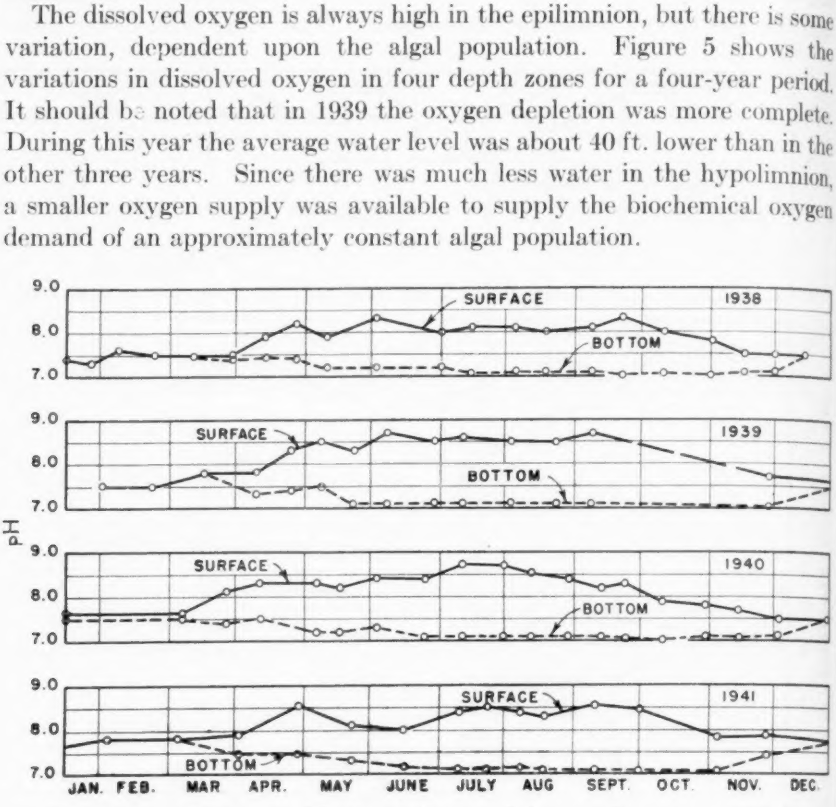

FIG. 6. pH of Surface and Bottom Water of Calaveras Reservoir—1938–41

Figure 6 shows the pH of the surface and bottom water for the same four-year period. The surface water has a pH of above 8.0 from April to October and the pH of the bottom water is 7.1 from May to December. The surface pH values were higher in the summers of 1939 and 1940, indicating greater algal growths. Inspection of Fig. 5 shows a more rapid depletion of dissolved oxygen, due to the death of these algae.

There is some variation in the annual cycles of Lower Crystal Springs Reservoir for different years, as could be expected of a reservoir which borders on an unstable stratification condition. The surface temperatures are at a minimum in January and February and begin to rise in March or April. They continue to rise, reaching a maximum sometime in July; then, slowly, begin to decrease. The dissolved oxygen content remains

high throughout the reservoir until May when it begins to decrease near the bottom. As the summer progresses, the dissolved oxygen shows a gradual decrease from top to bottom until the transition zone forms, usually in July or August, at which time the decrease is much sharper in this zone. This thermocline usually begins at from 50 to 55 ft. when it forms in August, but when it begins in July or as early as June, the stratification begins in some years as shallow as 35 ft. from the surface. In these cases, however, the thermocline is not definite and often disappears, though if it does, it forms again as the thermocline is evident in September of each year. Normally, the zone begins dropping very slowly in October but the reservoir is not in complete circulation until sometime in December.

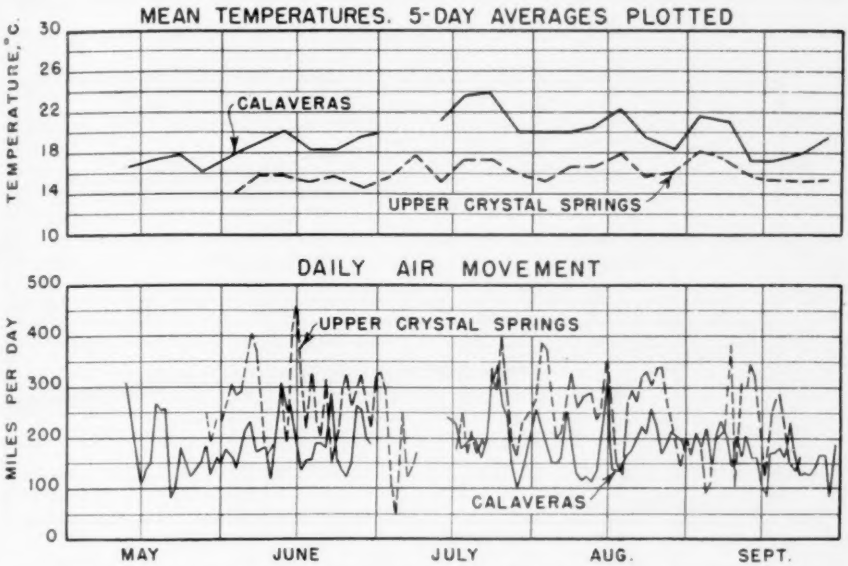

FIG. 7. Weather Data at Calaveras and Upper Crystal Springs Reservoirs—May–September 1941

The pH of the surface water normally rises in March or April and remains high throughout the summer. The pH of the bottom water begins decreasing in May or June, and, after stratification in July or August, the pH of the hypolimnion remains constant at 7.1 or 7.0 until the period of complete circulation in December.

Weather Data and Heat Distribution

Weather Data

To show why the thermal changes in the two reservoirs are so different, air movements and air temperatures at or near the reservoirs were recorded for a short period in 1941. No weather data could be collected at

Lower Crystal Springs Reservoir so data collected at Upper Crystal Springs Reservoir are used. Occasional checks showed that air movement was about the same in both places, although the mean temperatures on Lower Crystal Springs seemed to be one or two degrees higher than at the point where observations were made. This should be taken into consideration when inspecting Fig. 7. The average difference in maximum and minimum air temperatures from which the mean temperatures graphed were calculated is about 10°C. for the period June to October at Calaveras, as compared with an average difference of 5° or 6°C. at Lower Crystal Springs Reservoir. Total daily air movement was measured because no apparatus was available for charting wind velocities throughout the day, but maximum wind velocities range from 5 to 10 per cent of the total daily movement.

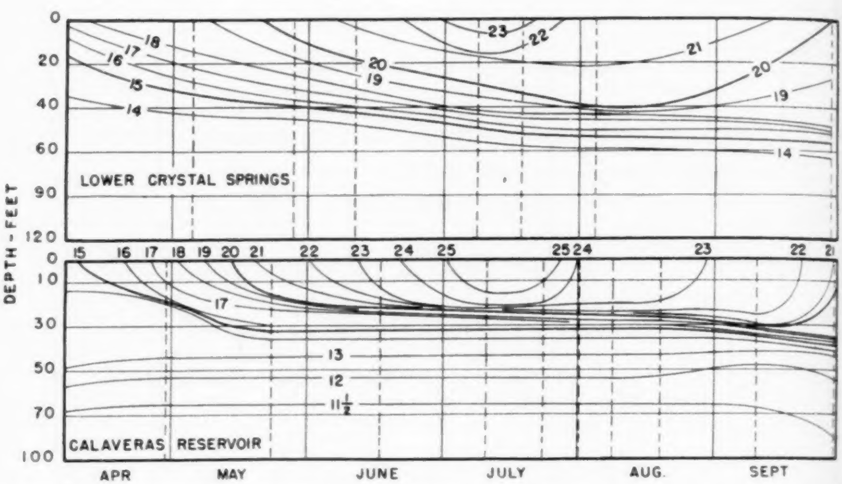

FIG. 8. Isotherms of Vertical Sections of Calaveras and Lower Crystal Springs Reservoirs—April–September 1941

Figure 7 shows the daily air movement in miles per day and the mean air temperatures in degrees Centigrade for the period May to October for both reservoirs. Figure 8 is an isotherm sketch of a vertical section of the two reservoirs for the period April to October 1941. Table 1 is a heat budget, showing heat gains and losses for each reservoir from January to October 1941. The heat content of each reservoir was listed as zero for January, although Lower Crystal Springs Reservoir contains 5,500 calories per sq.cm. per 120-ft. depth more than Calaveras Reservoir, because minimum temperatures are 12.0° and 10.5°C., respectively. From January until April 15, Lower Crystal Springs Reservoir has absorbed 10 per cent

more heat and the heat is more widely distributed throughout the reservoir depth than at Calaveras Reservoir.

The air movement at Calaveras Reservoir averages about 190 mi. per day during May and June. More heat is absorbed by the surface water in May than in any other month. The winds are strong enough to mix only the upper 20 or 30 ft. of water, so that the transition zone forms at this time. After the formation of the transition zone, the thermal resistance

TABLE 1

*Heat Budget for Calaveras and Lower Crystal Springs Reservoirs, January–September 1941**

(Calories per Sq.Cm. of Surface for 120-Ft. Lake Depth)

DATE	CALAVERAS		LOWER CRYSTAL SPRINGS	
	Total Increase	Δ Increase	Total Increase	Δ Increase
January	0		0	
		7,440		8,160
Apr. 15	7,440		8,160	
		1,410		1,290
Apr. 30	8,850		9,450	
		2,290		1,060
May 15	11,140		10,510	
		1,660		1,390
May 31	12,800		11,900	
		1,080		1,310
June 15	13,880		13,210	
		1,650		1,650
June 30	15,530		14,860	
		470		1,200
July 15	16,000		16,060	
		−790		−90
July 31	15,210		15,970	
		−380		−20
Aug. 15	14,830		15,950	
		−70		−360
Aug. 31	14,760		15,590	
		360		−600
Sept. 15	15,120		14,990	
		−880		−760
Sept. 29	14,240		14,230	

* Lower Crystal Springs Reservoir contains about 5,500 calories per sq.cm. of surface area per 120-ft. depth more than Calaveras Reservoir during the period of minimum water temperature in winter.

to mixture increases with additional absorption of heat, so vertical circulation becomes increasingly difficult to attain as the summer advances.

The few observations made in May and the daily air movement recorded in June show an average wind movement of 270 mi. per day during this period at Lower Crystal Springs Reservoir. Heat is absorbed more gradually during May and June than at Calaveras and is distributed throughout a greater depth of water. The heat absorption during the

last half of June is the highest of any half-month period and the beginning of a thermocline formation at the 40-ft. depth is apparent in early July. The observations taken to date show that the most definite stratification characteristics are apparent after this reservoir has passed its period of maximum heat content.

TABLE 2

Total Mineral Content Variation in Calaveras Reservoir on Various Dates Throughout 1940, as Indicated by Conductivity Measurements

DEPTH IN FEET	CONDUCTIVITY, $K \times 10^5$ OHMS^{-1} — Dates of Measurement								
	1-17-40	3-27-40	5-6-40	6-4-40	7-11-40	8-13-40	10-11-40	11-14-40	12-3-40
Surface	22.1	21.1	22.4	22.9	23.5	25.0	25.0	24.8	23.8
15	—	—	23.3	23.1	—	25.1	25.4	—	—
20	—	—	23.0	23.0	24.2	—	—	—	—
25	23.2	21.2	22.9	—	23.8	25.1	25.4	24.7	23.8
30	—	—	22.6	—	22.6	22.6	25.4	—	—
35	—	—	21.8	21.6	21.6	—	23.9	24.9	—
40	—	—	—	—	—	21.1	21.5	23.3	23.9
50	22.8	20.8	20.6	20.0	20.6	20.8	21.0	21.0	24.0
75	—	20.7	20.3	20.0	20.5	20.9	22.0	21.9	23.5
100	22.2	20.4	20.0	20.0	20.9	22.0	23.3	—	—
Bottom	—	20.6	20.8	21.3	22.8	25.0	25.0	25.0	25.0

TABLE 3

Partial Chemical Analysis of Calaveras Reservoir Water at Various Depths in March and August 1940

DEPTH IN FEET	MARCH 27, 1940			AUGUST 13, 1940		
	Alkalinity in ppm.	Chlorides in ppm.	Hardness in ppm.	Alkalinity in ppm.	Chlorides in ppm.	Hardness in ppm.
Surface	80	5.5	88	94	5.5	103
50	78	5.5	88	77	5.5	87
100	77	5.5	88	—	—	—
Bottom	78	5.5	88	85	5.5	105

The average surface water temperatures of each reservoir were higher than their respective mean 5-day average air temperatures from May to October, except for a few days in July at Calaveras. This indicates that the net result of heat conduction between the air and water surface is a heat loss from the reservoir. From May to July this loss was more than compensated for by the heat gains from radiant energy, but, after July, heat losses exceeded the heat gains, resulting in a decrease in the total heat content of the reservoir water.

It is interesting to note that the total heat increase for the year is the same for both reservoirs—about 16,000 calories per sq.cm. per 120-ft. depth—and is reached in about the middle of July. This heat increase is the same although the minimum water temperature in Calaveras Reservoir during the winter is about 1.5°C. less than in Lower Crystal Springs Reservoir, and the maximum surface water temperature in summer is about 2°C. higher. The compensating factor is the difference in heat distribution.

Chemical Variations With Depth

The chemical variations with depth in Calaveras Reservoir are given in Table 2, which shows the conductivity of water collected at various depths throughout 1940. These conductivities show the variation in total dissolved solids, but give no indication of the specific mineral content. If the conductivity which is expressed as $K \times 10^5$ ohms^{-1} is multiplied by a constant, 5.3, the quotient is equal to the total dissolved solids, excluding silica, in parts per million. In the table it is shown that mineral content is constant throughout the reservoir depth during the circulation period in winter, the concentration being dependent upon runoff. After the thermal zones are formed, mineral content increases in the epilimnion, usually to about a 15-per cent increase by August or September, due to drainage water and some concentration of the epilimnion by evaporation. The water in the hypolimnion, except near the bottom, shows no change in mineral content from spring until the reservoir turns over in late fall.

Table 3 gives the results of a partial chemical analysis of the water of Calaveras Reservoir at different depths in March and August 1940.

Plankton Growths

Diatoms are the predominating organisms in both reservoirs during the winter months. They are also present throughout the other months of the year and very often are most numerous. *Synedra* is the most common diatom and *Stephanodiscus* and *Asterionella* are quite plentiful. The predominance of the Chlorophyceae, or green algae, occurs only during the summer or early fall, but they are not always the most plentiful organisms during this period. The two organisms of this group which have been observed in large numbers are *Staurastrum* and *Mougeotia*. Crustacea are present the year around and very often make up the major volume of the catch. The Rotifera are also present the year around and are found in largest numbers in summer and early fall. The most troublesome Protozoa is *Ceratium* which has predominated at some time or another in all seasons. *Mallomonas* is another protozoa which has occurred in large numbers on a few occasions. *Anabaena* and *Aphanizomenon* are by far the most important of the Cyanophyceae, since, both living and

dead, they are the cause of tastes and odors. These organisms have been present in large numbers during every month of the year but occur less often in winter than in the other seasons.

Copper sulfate treatments are used to control these plankton growths. A survey of the treatment records for the past ten years shows that copper sulfate has been added to Lower Crystal Springs Reservoir during every month of the year, though, of course, these treatments do not occur each month every year. As a general rule, about three treatments are made each year, the most common months for treatment being June and September. Calaveras Reservoir has received treatments in each month from May to December during one year or another. On an average, however, there are two treatments a year, the most common months for treatment being May and August. The blue-green algae, *Anabaena* and *Aphanizomenon*, necessitate the majority of treatments, but at times it is necessary to control the growth of *Ceratium*, *Mougeotia* or the general growth of all algae, protozoa and diatoms.

Conclusions

Reservoirs in the San Francisco Bay area can be expected to stratify at depths varying from 20 to 60 ft., depending upon weather conditions, provided that the water is of sufficient depth.

There is a marked change in pH and dissolved oxygen as well as temperature in the transition zone.

Each reservoir observed has its own stratification characteristics, which are practically the same each year.

In the reservoirs of this locality which stratify, the "fall overturn" is a gradual process, as about two months elapse between the time that the thermocline begins dropping to a lower water level and the time that the reservoir is in complete circulation.

In a reservoir having stratification characteristics similar to Calaveras, aeration facilities are advisable if water is to be drawn from the transition zone or below during the stagnation period.

Both reservoirs absorbed about the same amount of heat per unit area for an equal depth (120 ft.) between the time of minimum water temperature in winter and the time of maximum water temperature in summer, although their heat distribution with depth was very different.

A knowledge of the quality of water in a reservoir from top to bottom and the changes which take place throughout the year are of great help in obtaining the best quality of water from that reservoir.

These studies indicate that much is to be gained by having outlet structures designed so that they may be operated to draw from several water levels.

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Copper Sulfate Dispersion and Settlement

By H. C. Medbery

TO DETERMINE the efficiency of dispersion with the methods of copper sulfate treatment used by the San Francisco Water Department, and the period of time after treatment that copper remains in suspension, numerous tests were made on Lower Crystal Springs Reservoir after treatment on May 6, 1941. The results of these tests are listed in Table 1. Copper content of the samples collected was determined colorimetrically using the sodium diethyldithiocarbamate method as described in *Standard Methods*.* Apparently some copper was in solution in the reservoir before treatment as the tests indicate more copper than was added, but no analyses were made before treatment.

Copper sulfate is applied by dissolving a known quantity in water and spraying it over the surface of the water behind a motor boat. Tests showed the wake of the boat to have some mixing effect for 300± ft. on either side in the wider sections. The highest copper concentration found in the surface water an hour after treatment was 0.18 ppm., and not one of about 40 scattered tests on the surface water showed an absence of copper. Tests showed, too, that some copper had reached the bottom within the first three hours.

Three days were required for complete treatment and on May 14, copper concentration was nearly constant throughout the reservoir in spite of the

A further discussion of one phase of the previous paper.

* *Standard Methods for the Examination of Water and Sewage*. Am. Public Health Assn. and Am. Water Works Assn., New York (8th ed., 1936).

fact that copper sulfate was added according to surface area, thus adding more per volume of water in the shallow than in the deep sections.

The copper which precipitated out as a hydroxide apparently did not tend to settle out until five weeks after treatment. At the end of six weeks the copper hydroxide in suspension in the surface water had settled out as the copper concentration of the surface water was only slightly over 0.03

TABLE 1

Copper Concentrations in Lower Crystal Springs Reservoir at Various Depths After Treatment

(17.2 lb. per acre $CuSO_4$ added May 6, 1941)

DEPTH IN FEET		COPPER, IN PPM. AT VARIOUS TIMES AFTER TREATMENT						
		1–3 Hr.	1–3 Days	5–8 Days	21 Days	35 Days	42 Days	48 Days
Surface	Max.	.18	.09	.07	.07	.07	.03+	.04
	Min.	.06	.04	.04	.05	.03	.03+	.03
	Avg.	.10	.06	.06−	.06	.05	.03+	.03+
15	Max.	.24	.08	—	—	.08	—	—
	Min.	.04	.04	—	—	.04	—	—
	Avg.	.08	.06−	.06	.06	.07	—	—
30	Max.	.07	.06	—	—	.13	.06	—
	Min.	.03	.03	—	—	.10	.05+	—
	Avg.	.05	.03	.06	—	.11	.06−	—
50	Max.	.14	.05	—	—	.25	.10	.08
	Min.	.03	.04	—	—	.09	.08	.04
	Avg.	.08	.04+	0.6	.05	.17	.09	.07
75–100	Max.	.09	.07	.06	.07	—	.10	.11
	Min.	.02	.04	.03	.07	—	.08	.09
	Avg.	.05	.05+	.05−	.06+	.09	.09	.10
Over 100	Max.	.06	.06	.06	.06	—	—	—
	Min.	.03	.05	.03	.06	—	—	—
	Avg.	.04	.05+	.04+	.06	.07	.11	.09

ppm., which is about the solubility of copper in water. The copper continued to settle out slowly until 48 days after treatment at which time algal growths appeared and necessitated another addition of copper sulfate.

Similar tests were made on Calaveras Reservoir which was treated May 19. The suspended copper hydroxide in the surface water settled out faster than at Lower Crystal Springs because of the warmer surface water temperature. Otherwise, results were approximately the same.

Materials Requirements for U.S. Public Water Supply Construction and Maintenance

By Harry E. Jordan

FAIRLY early in 1941, it became evident to many that the country's military production program would place an unprecedented demand upon all industrial facilities and materials. It also became evident that a record of needs for critical items in any national field was necessary in order that available stocks of raw materials might be directed as fully as safely possible to military uses. Along with this, it has been understood that certain civilian services are as essential to the national program as much of the direct military material. Public utility services, such as water supply and electric power, as well as fuel, transportation and the like, must be in a position to render full service if the national production program is to go forward successfully.

Since July 1941, an exchange of information has been in progress between the American Water Works Association and the War Production Board. As data of value were developed by the A.W.W.A., they have been placed in the hands of War Production Board staff members. Now it appears useful to place some of the figures in the published record.

Method of Development of Information

It is important to record the method of development of the statements herein contained. In July 1941, a request for certain information was sent to the heads of water departments in all United States cities of more than 10,000 population. The items covered were: distribution pipe, valves, hydrants, special castings, service line materials, service line fittings, and meters. The information collected covered: normal annual consumption of each item, reserve stock of each item as of January 1, 1940, reserve stock of each item as of January 1, 1941, consumption of each item during

A presentation by Harry E. Jordan, Secretary, A.W.W.A. In the preparation of this compilation and analysis, A.W.W.A. President Louis R. Howson has given very substantial co-operation, without which this presentation could not have been developed. The superintendents of the large water plants have co-operated most effectively in submitting data, and manufacturers of water works materials have been very helpful in reviewing tabulations.

1940, and estimate of requirements for 1941. Returns were received from departments serving more than 40,000,000 of the estimated 82,000,000 persons who used public water supply in the United States in 1941. The distribution of population by sizes of cities is shown in Table 1.

TABLE 1

Distribution of Population by Sizes of Cities in the United States

Population Grouping for Water Supply Study

POPULATION RANGE	TOTAL PERSONS IN GROUP (THOUSANDS)	CUMULATIVE TOTAL
Over 5,000,000	7,468*	7,468
500,000–5,000,000	14,913	22,381
300,000–500,000	5,895	28,276
200,000–300,000	3,226	31,502
100,000–200,000	6,500	38,002
50,000–100,000	7,344	45,346
30,000–50,000	5,650	50,996
10,000–30,000	11,734	62,730
Less than 10,000	19,270	82,000
Estimated total served by public water supply	82,000	

1940 Census Distribution of Incorporated Communities†

POPULATION GROUP	NO. OF CITIES	CUMULATIVE TOTAL
Urban places:		
1,000,000 and over	5	5
500,000–1,000,000	9	14
250,000–500,000	23	37
100,000–250,000	55	92
50,000–100,000	107	199
25,000–50,000	213	412
10,000–25,000	665	1,077
5,000–10,000	965	2,042
2,500–5,000	1,422	3,464
Incorporated Rural Places:		
1,000–2,500	3,206	6,670
Less than 1,000	10,082	16,752

* This figure is not the 1940 census population of New York City, but a water department statement re population served by the New York City public water supply.

† Based on "Population in Groups of Places Classified According to Size, and in Incorporated Rural Territory, for the United States. 1940 and 1930," Series P-3, No. 13, May 31, 1941, Bureau of Census. Incorporated places without population are not included in this table.

Certain characteristics of the water supply field make the production of consolidated information a difficult and time-consuming operation. There are about 12,800 water works plants in the United States. Over 9,300 of these are municipally owned and operated. Except in a few states, such as Wisconsin and Indiana, there is little control over municipal water plant accounting, so these plants cannot furnish statistical information promptly. The 3,400 (plus) privately owned plants are more accustomed to controlled reporting but, with a few exceptions, confine their operations to population groups of less than 100,000 persons. This situation became a matter of concern when it appeared advisable to separate *new construction* from *maintenance and repair* requirements for water works. Not enough of the cities carry their records clearly separated to make the collection of information at the point of use worth the time required to develop it.

Engineering Data Available

Fortunately, the Association's president, Louis R. Howson, is an engineer of long experience in the field of appraisal and valuation of water works properties. His firm, Alvord, Burdick and Howson, has been engaged in this practice for more than 40 years and has developed information from a substantial group of cities. There have been made available the condensed data from this firm's office, covering 102 cities ranging in population from 3,000 to 2,000,000 persons. Included in these studies are 19 cities pumping water directly from lakes or rivers, 14 having impounded gravity supplies and 29 having ground water supplies. Forty complete purification systems are included.

Basic Data

The information derived from this office has been reviewed by other engineers and by various manufacturers. It has also been studied in comparison with the information derived from the 1,077 cities of over 10,000 population. Table 2 gives, in condensed form, the construction and maintenance needs, per 1,000 persons served, for each major category of water supply. The overall significance of the table can be compressed into two statements:

For each 1,000 persons served from public water supply, approximately 300 tons of metal are required for construction of the works.

For the maintenance and repair needs of the installed water systems, nearly 5 tons of metal are required annually per 1,000 persons served.

In the development of the construction requirements figures, certain items have been found difficult to appraise. For example, while 6,475 water works depend upon ground water for their supply, the greater pro-

portion (by number) of such supplies are in smaller communities. A much greater number of wells is used in industry and in private supplies than is used for public water supply. The tonnage figure for wells is

TABLE 2

*Condensed Summary of Requirements of Principal Water Works Installation Materials**

KEY: Column 1—Amount installed per 1,000 persons served, *tons*
Column 2—Estimated number of persons served, *millions*
Column 3—Total material installed for population served, *tons*
Column 4—Turnover period, *years*†
Column 5—Annual requirement for maintenance and replacement, *tons*

	NO. 1	NO. 2	NO. 3	NO. 4	NO. 5
Production:					
Well tubing and pumps	1.6	30	48,350	20	2,400
Impounded, lakes and springs	2.0	20	40,000	40	1,000
Filtration works	11.5	32	368,000	30	12,300
Storage tanks or reservoirs	3.0	82	246,000	40	6,150
Pumping and boiler equipment	12.0	80	960,000	40	24,000
Distribution:					
Mains‡	275.0	82	22,550,000	75	300,670
Specials	11.0	82	902,000	75	12,025
Valves	3.0	82	246,000	40	6,150
Hydrants	4.0	82	328,000	30	10,930
Valve boxes	0.5	82	41,000	30	1,370
Service boxes	2.5	82	205,000	30	6,800
Service line fittings	0.5	82	41,000	30	1,375
Service pipe—copper	3.4	40	136,000	40	3,400
Service pipe—lead/iron§	6.8	42	272,000	20	13,600
Meters	1.73	60	103,850	30	3,460
Total annual turnover tonnage					405,630

* This summary does not take into separate account special items of equipment accessory to major operations. Boiler plant and pumping accessories, chlorinators, etc., represent a very substantial dollar value, in the aggregate, but should be considered to be included in the tonnage figures above.

† Based on studies of a group of individual systems, with adjustments downward to reflect war conditions.

‡ On the basis of cast-iron, adjusted to include some other materials.

§ Combination service made up of lead gooseneck and iron pipe. All-lead services not taken into account.

based upon: 200 ft. of 8-in. casing per well; 2.5 well units per city served; 1,000 lb. per unit for pumps and accessories; 6,475 cities served from ground water sources. From these basic units the first item in Table 2 was developed.

Impounded gravity supplies are difficult to evaluate on a wide basis. The tonnage installed on such systems varies widely with the distance from the source of supply to the city served. The figures given are necessarily subject to further study. Pumping equipment requirements vary widely. Steam plants with triple-expansion pumps still serve well in many cities. In other cities electric-driven centrifugal pumps are used. The tonnage figures given in Table 2 are weighted experience figures based upon wide study. The fact that several large cities neither install, own nor maintain meters connected to their water lines makes an absolute statement regarding meters difficult. The figures given have been carefully checked with meter manufacturers and are as accurate as it is possible to make them.

TABLE 3

Primary Materials Required for Water Works Maintenance Exclusive of Cement, Lumber, etc.

	PERCENTAGE OF VARIOUS MATERIALS IN UNITS INSTALLED							
	Iron	Steel	Brass or Bronze	Copper	Lead	Nickel	Rubber	Miscellaneous
Well tubing and pumps	5	90	5					
Impounding reservoirs	75	20	5					
Filtration works	20	70	7		1	0.5	0.5	1
Storage tanks and reservoirs		98	2					
Pumping equipment	40	50	7		1	0.5	0.5	1
Distribution mains	100							
Special castings	100							
Valves	91.5	2	6.5				tr.	
Hydrants	86.5	7.75	4.5		1		0.05	0.2
Valve boxes	100							
Service boxes	75	25						
Service line fittings			100					
Service pipe—copper				100				
Service pipe—lead/iron		80			20			
Meters	24.6	1.5	71			0.9	1.7	0.3

Primary Materials in Water Works Structures

In order to develop a breakdown of the critical metals required for maintenance and repair, a review has been made of the character of materials going into different plant units. No heading is set up to cover lumber, cement, sand, masonry, etc. Table 3 records the figures as they have been developed.

Annual Maintenance and Replacement Needs

For the present moment, the very important data required cover the needs of water works for metals used to maintain existing structures. In Table 2 a "turnover period in years" has been set up for use in relating installed construction tonnage to annual maintenance needs. The term "turnover period" is not set up to parallel "useful life" or "depreciation period."

TABLE 4

Annual Tonnage Requirements for Maintenance and Replacement

	IRON	STEEL	BRASS OR BRONZE	COPPER	LEAD	NICKEL	RUBBER	MISCELLANEOUS
Well tubing and pumps	120	2,160	120					
Impounding reservoirs	750	200	50					
Filtration works	2,460	8,610	860		125	60	60	125
Storage tanks and reservoirs		6,025	125					
Pumping equipment	9,600	12,000	1,680		240	120	120	240
Distribution mains	300,670							
Special castings	12,025							
Valves	5,625	125	400					
Hydrants	9,450	850	495		110		5	20
Valve boxes	1,370							
Service boxes	5,100	1,700						
Service line fittings			1,375					
Service pipe—copper				3,400				
Service pipe—lead/iron		10,880			2,720			
Meters	830	50	2,480			30	60	10
Sub-total	348,000	42,600	7,585	3,400	3,195	210	245	395
Basic metals in bronze*				5,690	2,540			1,705
Totals	348,000	42,600		9,090	5,735†	210	245	2,100

* Bronze tonnage broken down as Copper-Zinc-Tin-Lead @ 75-17.5-5-2.5% and totaled under Basic Metals total.

† Lead total includes 2,350 tons for calking one-third of the pipe and fittings installed @ 2.25% tonnage of iron.

The figures shown in Column 5 of Table 2 have been developed to show the magnitude of the annual need for maintenance metals in each category of water service. The percentage figures in Table 3 have been applied to the total figures in Column 5 of Table 2, and Table 4 has thus been

developed. This brings to clear view the annual needs for metals for maintenance of public water supply for the 82 million urban or near-urban citizens of the United States. It shows the following primary needs: 348,000 tons of cast iron, 42,600 tons of steel, 9,090 tons of copper, 5,735 tons of lead, 2,100 tons of zinc, tin, aluminum, etc., 210 tons of nickel, 245 tons of rubber. These are maintenance and minor replacement needs—not construction needs.

Application of the Construction Requirements Data

The figures given in Column 1 of Table 2 have a general applicability to the problems of expanding water works. The figures under the "*Production*" category should be understood not to be cumulative. There may be cities which derive a composite supply from both ground and surface sources, or with and without filtration, but generally a city's supply will be ground water or surface water; impounded water, without filtration, or surface water, filtered; from gravity sources or requiring pumping. Thus, one or another unit of the tonnage requirements will apply. In the "*Distribution*" category, however, the successive figures are cumulative, with the exception of service line materials. Either copper or iron pipe (with lead gooseneck) services may be used. Both may be used in the same city, but both will not be be used in the same service line. In the aggregate, 300 tons of metal will be required for construction of the distribution system to serve 1,000 persons. One or another substitute material may be considered from time to time, but often the reduction in required tonnage is overestimated at the time the substitution is made.

It is important to point out to agencies, which may wish water works executives to extend their distribution systems at the present time, that the aggregate of metals required to serve a new and geographically isolated unit with water, along with the other utility service requirements for electricity, gas, transportation, sewers, etc., may far outweigh the land purchase or other economies associated with the new project, viewed only within itself. This same partial understanding has affected the reasoning of certain individuals who have opposed metering of water services in wartime constructed facilities. In terms of tons required, water meters consume a little over 0.5 per cent of the metal used in water distribution, but meters serve to reduce the individual customer's waste of water. If the tendency to waste is not controlled by meters, equivalent service can be rendered only by installing many more tons of pumps, mains and all accessory items. This increase in total tonnage required for unmetered service is no less than 25 per cent of the 300-plus tons required for normal service. It can, therefore, easily be understood that, when all the data

are before a person for consideration, he will not fall into the error of saving metal in meters and consuming much more metal in other units as a result of the assumed saving.

Somewhat the same error is apparent in the current restriction of the use of copper in water service lines. In terms of required total tonnage, much less copper service pipe is required in the aggregate to serve each 1,000 persons connected to a water system than when ferrous metals are used. A materially less amount of copper is needed each year to replace existing installations than when ferrous metal services are installed. Every nation geared to war production is forced to allocate copper. The objective of all good citizens is to co-operate to the end that this allocation be as wise as it can be made.

TABLE 5

Normal Annual Requirements per 1,000 Population

(Population groups as shown in Table 1)

POPULATION GROUP	(1) MAINS	(2) VALVES	(3) SPECIAL CASTINGS	(4) HYDRANTS	(5) SERVICE LINE MATERIALS	(6) SERVICE FITTINGS	(7) METERS
	tons	*units*	*units*	*units*	*lin. ft.*	*units*	*units*
1	2.32	0.47	—*	0.24	—*	—*	—*
2	3.07	0.55	7.88	0.19	113.7	26.0	3.8
3	4.28	0.56	5.33	0.22	174.5	29.0	5.0
4	5.84	0.90	4.37	0.27	125.2	49.0	5.3
5	4.20	0.85	3.29	0.27	122.5	28.0	4.2
6	3.67	0.84	2.36	0.27	181.3	42.0	6.5
7	6.10	1.26	4.42	0.42	228.0	41.0	7.3
8	5.38	1.31	3.83	0.42	279.8	50.0	8.1
9	6.00	1.30	4.00	0.50	300.0	50.0	8.0

* No returns concerning special castings, service line materials, fittings and meters were made by New York City, since the water department does not install them.

Inventory of Water Works Materials

Reports covering the use of materials for repair, maintenance and operation are now required by the War Production Board. Large water plants file these reports on form PD-193. The 1941 survey made by the American Water Works Association covered annual requirements for, and year-end stores inventory on, certain major items. From these returns it is shown that, in the cities of more than 10,000 population, the normal year-end reserve of these items is a very substantial percentage of the annual consumption. The relation of year-end inventory to annual use (expressed in per cent) for various materials is:

Distribution pipe	56 per cent
Distribution valves	52 per cent
Special distribution castings	110 per cent
Hydrants	45 per cent
Service line materials	60 per cent
Service line fittings	94 per cent
Meters	30 per cent

These figures represent long term experience needs and cover the period prior to the time that wartime scarcity developed.

In the case of special castings, such as tees, ells, etc. used in distribution systems, the fact that the reserve inventory exceeds the annual use is not difficult to understand. When a special fitting of any size breaks in a water main, its replacement must be immediate. The variety of sizes involved adds to the number of units that must be held in reserve, or serious interruption to service would result every time a fitting had to be replaced.

Variations Due to Size of City

The survey clearly indicated the fact, known to engineers of wide experience, that the requirements for water service vary inversely as the population served. The larger the city, the more persons served per square mile of territory or per mile of main. The unadjusted figures covering normal annual requirements per thousand persons served are given in Table 5. The population groups are those shown in Table 1.

Summary

These analyses have made it possible to develop a considered summary of public water supply needs for critical materials. They are a safe basis of allocation of metals and are believed to include the amounts necessary to maintain the kind of water service needed to keep American industry and workers supplied with water. They show that, for every person served with water, not less than 600 lb. of metal must be installed, and that, to maintain and repair that installed material, 10 lb. of metal per year per person served are required.

Chlorine Consumed Tests for Pollution

By Harry A. Faber

WATER works men are presently interested in methods of determining the presence of casual or unusual pollution of a supply, either as it is prepared for distribution or as it is in the distribution mains on its way to the consumer. It is being recognized that the unexpected forms of possible pollution largely fall into the class of chlorine consuming substances. Thus the addition of a controlled amount of chlorine to a sample of water will, by the degree of its consumption, measure the presence of abnormal pollution. It is highly important to understand that the application of such a test must be a routine matter if the information desired is to have value. Either at the point of production of a supply or in the distribution system, there can be expected to exist some effect upon the test reagents hereinafter listed. The evidence of pollution will lie in the *deviation* from normal effects and will have to be interpreted in the light of the users' experience. Since even a qualitative test needs some precision, the following outlines are given with the suggestion that the information developed in any location will be more valuable if it is based upon a suggested standard or uniform procedure.

Methods A and B should yield comparable results, except for the greater accuracy of method B. For a few waters which exhibit an unusual reaction with chlorine (due to the presence of hydrogen sulfide, industrial wastes, etc.), it may be necessary to increase the chlorine dose. If a 5-ppm. dose does not give a measurable residual in the water under normal conditions, the test should be repeated using a dose of 10 ppm. or more, until a residual approaching 5 ppm. is present after 10 min. This dose should be used for subsequent tests on the same water supply.

Method C will not give results comparable to methods A and B, but is designed as a rapid plant control test to indicate a sudden increment in mass pollution and to provide a relative measure of its extent.

A contribution by Harry A. Faber, Research Chemist, The Chlorine Institute, New York.

All three methods provide only a non-specific test procedure. When gross pollution is indicated by these tests, further investigation by a sanitary survey or by specific tests for contaminants must be resorted to.

A. Field Method (Qualitative Test)

1. *Equipment:* One 4-oz. bottle, calibrated at 100 ml. (3.5 oz.); one rubber bulb dropping pipette; one bottle ortho-tolidine with measuring pipette; and one bottle "Zonite" (1 per cent sodium hypochlorite).

2. *Procedure:* Place 100 ml. of water sample in the 4-oz. bottle and add one drop of "Zonite" solution. This provides a chlorine dose of approximately 5 ppm. Mix and allow to stand. After 10 min. add 2 ml. of ortho-tolidine reagent to the water sample.

3. *Interpretation:* Residual chlorine in the sample should be sufficient to develop a bright yellow color within 1 min. If only a faint yellow color develops, or if there is no color, pollution is indicated, and a more detailed investigation should be made.

B. Field Method (Quantitative Test)

1. *Equipment:* Two 4-oz. bottles; one 100-ml. graduated cylinder; one 5-ml. pipette; one 1-ml. pipette; one comparator outfit for residual chlorine; and one bottle "Zonite" (1 per cent sodium hypochlorite).

2. *Procedure:* (Standard hypochlorite solution. Each 1 ml. of "Zonite" contains 10 mg. of chlorine. Place 95 ml. of distilled water in a 4-oz. bottle, add 5 ml. of "Zonite," and label this "Hypochlorite Test Solution." This is of such strength that 1 ml. added to 100 ml. of water is equivalent to a 5-ppm. chlorine dose. The solution deteriorates and should be used for only one week.)

To 100 ml. of water sample in a 4-oz. bottle, add 1 ml. of the hypochlorite test solution. Mix and allow to stand. After 10 min. pour 25 ml. from the bottle into the graduated cylinder. Make volume up to 100 ml. with distilled water. Mix and pour a sample into the comparator tube. Add ortho-tolidine and determine residual chlorine. Multiply the residual reading by 4 and subtract this result from 5; the difference equals chlorine consumed.

3. *Interpretation:* The chlorine consumed value will ordinarily be less than 1 ppm., but the normal value for a given water should be determined at regular intervals. If the chlorine consumed value deviates from the normal value to an extent approaching 5 ppm., the presence of pollution is indicated. A high chlorine consumed value should be investigated in greater detail.

C. Laboratory Method

1. *Equipment:* Refer to *Standard Methods.** For preparation of chlorine water see p. 165. For titration of residual chlorine by the neutral starch iodide method, see p. 231.

2. *Procedure:* To a 500-ml. sample of water in a 1-l. glass-stoppered bottle, add chlorine water sufficient to provide a 50-ppm. dose. Stopper the bottle, swirl gently to mix, and place in the dark. After 10 min., remove a 100-ml. sample and titrate residual chlorine by the neutral starch iodide method. Using 100 ml. of sample and titrating with 0.1 N thiosulfate, residual chlorine in ppm. = 3.546 × ml. thiosulfate required. Chlorine dose minus chlorine residual equals chlorine consumed.

3. *Interpretation:* The usual normal variations in chlorine consumed value for a given water at a given sampling point *must* be known. An abnormal increase in chlorine consumed would indicate the presence of pollution. This might be due to war gases, etc. For example, a normal chlorine consumed value of 3 to 4 ppm. might be increased tenfold before the toxicity limit of the poison involved would be reached. Any increase in chlorine consumed should be investigated.

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* *Standard Methods for the Examination of Water and Sewage.* Am. Public Health Assn. and Am. Water Works Assn., New York (8th ed., 1936).

Supply and Treatment Problems in South Dakota

By Everett R. Mathews

THE quality of South Dakota waters, both ground and surface, leaves much to be desired. First, they are extremely hard, South Dakota being one of the five hard water states in the country. A high total mineral content and considerable amounts of sodium salts also add to the undesirable character of the supplies. In addition, most of the ground waters contain objectionable amounts of iron and, often, manganese, and the few streams that have sufficient flow to serve as sources of supply without artificial storage are very turbid with silt, though they contain little organic matter. Finally, the impounded waters are subject to algal growths, which result in objectionable tastes and odors.

Closely related to the water quality problem is the factor of precipitation. The average normal annual precipitation for the state is 19 in., normal rainfall varying from 15 in. in the western part to 26 in. in the eastern part of the state. Extreme variations from the normal are not uncommon; for instance, during 1936, precipitation was only 57 per cent of normal over the whole area. Naturally, some communities received much less rainfall than this average. Because of this lack of plentiful rainfall, the securing of an adequate municipal water supply is often difficult, and since obtaining a supply of sufficient quantity is of primary importance, the matter of quality often plays a secondary rôle in the selection of a new source. Quality is then made satisfactory by modern water treatment processes.

Sources of Supply

The water-bearing Dakota sandstone formation underlies most of South Dakota. It outcrops in the Black Hills region and along the eastern slope of the Rocky Mountains in Wyoming, at which points surface water percolates into the porous sandstone forming a great reservoir under the state. The formation varies from 20 to 300 ft. in thickness. In many

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A paper presented on October 21, 1941, at the Missouri Valley Section Meeting, Cedar Rapids, Iowa, by Everett R. Mathews, Acting Director, Div. of San. Eng., State Board of Health, Pierre, S.D.

places it lies in sheets with streaks of shale separating the layers. Covering the formation is an impervious stratum of shale which keeps the water confined, and, as the formation dips toward the east, considerable pressure is developed. This sandstone is the source of water for most of the state's deep artesian wells, many of which are flowing wells. The wells vary in depth from 1,500 ft. in the north and central part to 300 ft. in the southeast. In the western half of the state, the formation lies from 2,000 to 3,000 ft. below the surface so that very few wells have penetrated it.

Unfortunately, this great aquifer yields a very low quality water as far as mineral make-up is concerned. Most specimens taken from it show a total mineral content ranging from 1,700 to 2,400 ppm. and a hardness content of from 600 to 1,200 ppm., a high percentage, usually about 50 per cent, of which is non-carbonate hardness. Iron and manganese are usually present in objectionable amounts and hydrogen sulfide gas is often encountered. In addition to these undesirable features, the water is generally quite corrosive to steel casings, thereby either making the life of a well quite short, or necessitating costly repairs. Some municipalities have used special cast-iron casings in an attempt to prevent this corrosive action. In some localities, too, the water contains objectionable amounts of fluorides, contents varying rather markedly. In three communities as much as 5 or 6 ppm. fluorides has been found, though, in general, the values run from 1.0 to 3.0 ppm.

While this water can be treated and rendered somewhat more palatable, it is usually more satisfactory, if at all possible, to find a different source of supply. Many of the larger cities that have used artesian water in the past have abandoned their wells and developed impounded surface supplies. The smaller cities have been unable to do this because of the expense involved, so they are still using the extremely mineralized water. Two of the smaller cities have built lime-soda softening plants, and, though chemical costs for operating the plants are quite high, the improved quality of the water is well worth the expense.

In a few of the river valleys in the eastern part of the state are located glacial deposits of gravel and sand. These deposits are only local ones, but in some few localities they furnish considerable amounts of water which may readily be obtained by means of shallow wells. Water in these formations comes from precipitation that percolates directly down to them, or from seepage from nearby streams or lakes. Water levels fluctuate considerably from season to season and from year to year.

The quality of the water in these shallow wells varies a great deal. In the best wells the water is usually only moderately hard and moderately mineralized, but contains objectionable amounts of iron and manganese. These supplies often require treatment for iron removal and sometimes

manganese removal, before they are useful as municipal supplies. Since people are continually demanding a higher quality water, it seems likely that some will also be softened within the next few years.

The Missouri River, which flows across the state in a southeasterly direction, offers the best possibilities of any stream within the state for surface water development. It has sufficient flow at all times to insure an adequate supply without artificial storage. The water, however, carries an extremely heavy load of silt, and, because of the high turbidity and the swiftness of the stream, algae growths, with their resultant tastes and odors, are unusual. The water is moderately hard, requiring softening to produce a good all-purpose water. Fortunately, lime softening works out very well in the purification process, so that the cost of purification and softening is very nearly as low as that for purification alone.

Other streams do not give sufficient flow at all times of the year to be used as sources of municipal water supplies without artificial storage. A number of streams have been developed, however, by building large dams and thus creating storage reservoirs. These impounded supplies have received greater attention than other types of supplies during the past few years. They appear to offer the best solution to the water problems of many South Dakota cities.

Waters in these storage reservoirs are usually low in turbidity, high in color and carry only a small amount of pollution. In the spring after the snow melts, the mineral content is ordinarily very low. On standing, however, the water gradually picks up minerals from the soil so that, by fall, the hardness is fairly high. Algae growths are troublesome if they are not controlled by periodic treatment with copper sulfate or some other algicide.

Well Supplies

Deep Wells

Of the 134 deep well supplies in South Dakota, only two receive treatment by softening. These are the supplies of Vermillion and Beresford which are treated by the lime-soda process without recarbonation. Sodium aluminate is the coagulant used. At present, both of these plants are the conventional type of softening plant. The Vermillion plant, however, is now being enlarged and improved so that it will soon include an "Accelator" up-flow softening unit and recarbonation equipment. Both plants reduce the hardness content to approximately 100 ppm. Polyphosphate stabilizers are being added to prevent the formation of calcium carbonate deposits in pipes and hot water heaters. An interesting feature of the Beresford treatment is the fact that the fluoride content is reduced from 2.5 to 1.8 ppm. through the removal of 25 ppm. magnesium.

Shallow Wells

Of the 42 shallow well supplies in the state, nearly all need iron removal and many should also be equipped for manganese removal. Actually, there are only seven iron removal and no manganese removal plants in operation. The process used at the iron removal plants has been aeration, sedimentation and filtration through rapid sand filters of either the gravity or pressure type. Following filtration, most of these waters are chlorinated.

The Sioux Falls supply is a typical example of a shallow well supply containing both iron and manganese. From wells located in the Big Sioux River valley, the city obtains a raw water containing objectionable amounts of both iron and manganese as well as a rather high hardness content. Analyses made recently show 3 ppm. iron, 1.6 ppm. manganese and a hardness content of 450 ppm. Total dissolved solids were found to be approximately 600 ppm.

An iron removal plant with treatment consisting of chlorination, aeration, sedimentation and filtration was put into operation in 1922, reducing iron content to about 0.3 ppm. The high manganese content is, however, still causing difficulties through deposits in pipes, especially service lines, stains on plumbing fixtures and stains on clothing in the laundry. The iron removal plant reduces manganese only about 0.3 ppm., leaving a residual of 1.3 ppm.

Experiments on Manganese Removal

Interest in the problem of manganese removal led to a series of experiments directed at determining what improvements to the present iron removal plant would be necessary for removal of the manganese. With the knowledge that small amounts of chlorine have been employed successfully to assist in manganese removal and the fact that break-point chlorination has been found effective in destroying objectionable tastes and odors, it seemed worthwhile first to try this method of manganese removal. The water appeared suitable for such experiments since it contained considerable ammonia nitrogen as well as much manganese. It was considered possible that the ammonia was helping to hold the manganese in solution, and it was known that through its reaction with the chlorine to form chloramines, it was, at least, slowing up oxidation of the manganese by chlorine.

For the experiments, several series of samples of raw water were collected and treated with progressively increasing doses of chlorine. After time intervals of 1, 3 and 20 hr., residual chlorine, ammonia nitrogen and residual manganese contents were determined. When the results were plotted, it was noted that a definite break in the chlorine curve occurred

at a dosage of 4 ppm., this point corresponding with the oxidation of ammonia nitrogen. At the break-point, all ammonia nitrogen was oxidized, but it was found that oxidation and precipitation of the manganese occurred rather slowly. After contact for 1 hr. very little manganese was removed; on 3-hr. contact at an 8-ppm. chlorine dosage, however, the manganese was entirely precipitated, thus indicating that the oxidation and precipitation reaction started at a point just after the break-point had been reached.

It was evident from these first experiments that high doses of chlorine would oxidize and precipitate the manganese, but that a long contact period was necessary. In an attempt to find a process to increase the speed of this reaction and to reduce the chlorine dosage, an experimental plant consisting of a chlorinator, coke-tray aerator, contact filter, settling basin and rapid sand filter was set up. The capacity of this unit was 10 gpm., with provisions for taking flows up to 20 gpm.

Complete data on the unit have not yet been gathered, but early results indicate that this process can be worked out successfully for the Sioux Falls water. At the present time, the various units in this experimental plant are showing the following manganese removal efficiencies: aerator and contact filter, 50 per cent; settling basin, 0 per cent; and rapid sand filter 50 per cent, making an overall efficiency of 100 per cent.

These results were accomplished with a chlorine dosage of 7 ppm., an aeration rate of 10 gpm. per sq.ft., a contact filtration rate of 5 gpm. per sq.ft., a settling period of 2 hr. and a rapid sand filter rate of 2 gpm. per sq.ft. Early results point to a lower chlorine dosage after the contact filter becomes more thoroughly seeded, but it appears that a dosage high enough for complete oxidation of the ammonia nitrogen will be necessary.

The optimum rates of flow through the several units have not yet been established. It is evident from the results obtained to date that the present iron removal plant can be made to remove both iron and manganese with comparatively few additional units. Iron removals with the experimental plant are somewhat better than those by the existing plant.

Surface Supplies

River Waters

As previously pointed out, probably the best source of surface water in South Dakota is the Missouri River. Unfortunately, however, none of the larger cities are located on this stream, so they do not have the advantages of its remarkably fine water. Five of the smaller cities are located on the river and three of them—Yankton, Chamberlain and Mobridge—use it as a source of supply. These are the only municipalities in the state using stream water without artificial storage.

The three plants all soften and coagulate the water with lime and sodium aluminate or lime and filter alum. None of them is now equipped for recarbonation, although at Yankton the installation of recarbonation equipment will be made soon. Two of these plants have been using polyphosphate compounds for stabilization. Because of the mineral characteristics of Missouri River water, the lime softening reactions go to completion quite readily and a reasonably stable water can be produced without recarbonation.

In the Mobridge plant, water is pumped to a presedimentation basin equipped with a mechanical sludge removal mechanism. Ordinarily, no chemical is added to the water in this basin, although facilities are available for adding alum whenever extreme turbidity conditions warrant it. After presedimentation, the water is treated with lime and sodium aluminate, mixed by mechanical flocculators and then allowed to settle. After a 6-hr. settling period it is ammoniated, chlorinated and filtered through rapid sand filters. Lastly, a phosphate stabilizer is added.

Average plant results, in parts per million, for the period of October 1, 1940 to October 1, 1941 are as follows:

Sample	*Phenolphthalein Alkalinity*	*Methyl Orange Alkalinity*	*Hardness*	*Residual Chlorine*
Raw	2	159	202	0
Settled	27	51	—	0
Filtered	23	44	110	0.25

Impounded and Natural Lake Waters

Six cities in the state use impounded or natural lake water supplies. These cities all employ rather complete treatment processes to get the desired quality water. Five of them soften as well as purify their water.

One of the South Dakota cities that abandoned artesian well water for an impounded surface supply was Aberdeen, a city of 17,000 population, located in the northeastern part of the state. The wells abandoned were all flowing wells with a water hardness of 810 ppm. The new supply was put into service in 1935. Raw water is impounded on Elm River and tributaries, with a drainage area of approximately 1,000 sq.mi. The original reservoirs consisted of a 1,400-mil.gal. primary reservoir and two diversion dams and reservoirs. Since the original installation, two more small dams and one more primary storage reservoir have been added to the system.

Treatment of this water is accomplished in a 4-mgd. water softening and purification plant using the excess lime-soda process. The impounded water has a low turbidity, contains considerable color and carries only a very small amount of pollution. It is not very highly mineralized, the average total dissolved mineral content being 390 ppm. Raw water

hardness ranges from 52 to 445 ppm. This water has the unusual characteristic of having a negative non-carbonate hardness content for part of the year, and a positive non-carbonate hardness the remainder of the time. Non-carbonate hardness values run as high as 30 ppm. and occur during, and shortly after, the spring runoff. Negative values can be expected during late summer and all winter. These values sometimes reach as high as 60 ppm., and the condition apparently is the result of the leaching out of sodium bicarbonate from the soil as the water stands in the reservoirs.

Luxuriant growths of algae appear during June, July and August, but are successfully controlled by applying copper sulfate from solution boxes on a boat. Only the lower two reservoirs are treated, since they contain a summer's supply of water. In general, algae have been well controlled with dosages of copper sulfate of 4 lb. per mil.gal. Three to six applications are required during a summer.

The Aberdeen filtration plant is a conventional type of lime softening plant using excess lime dosage and recarbonation. A coagulant—usually sodium aluminate—is employed with the lime and a second coagulant—alum—is used after recarbonation for coagulation of calcium carbonate.

The procedures in this process include addition of excess lime and sodium aluminate coagulant, mixing, settling, neutralization of excess lime with carbon dioxide gas, addition of alum coagulant, secondary mixing, secondary settling, secondary recarbonation, filtration and chlorination. Because of the sodium bicarbonate which the raw water often contains, it has been possible to turn out unusually soft water with lime as the sole softening agent. In the author's experience in operating the plant for several years, he often found it necessary to determine ways of keeping the water from coming out too soft. An extremely close vigil had to be kept on the lime dosage and the recarbonation treatment. It was attempted to carry the hardness between 40 and 50 ppm. This seemed to be the point at which this water had the best taste and at the same time, the most desirable characteristics for industrial uses.

Average plant results, in parts per million, for the period of October 1, 1940 to October 1, 1941 are as follows:

Sample	*Turbidity*	*Phenolphthalein Alkalinity*	*Methyl Orange Alkalinity*	*Hardness*	*Residual Chlorine*
Raw	—	5	221	224	0
Settled (before recarbonation)	—	102	127	—	0
Filtered	0	16	48	48	0.25

This supply has been a decided success and has furnished an excellent example for other cities in South Dakota wishing to improve their supplies.

ABSTRACTS OF WATER WORKS LITERATURE

Key. **31:** 481 (Mar. '39) indicates volume 31, page 481, issue dated March 1939. If the publication is paged by issues, **31:** 3: 481, (Mar. '39) indicates volume 31, number 3, page 481. Initials following an abstract indicate reproduction, by permission, from periodicals as follows: *B.H.—Bulletin of Hygiene (British); C.A.—Chemical Abstracts; P.H.E.A.—Public Health Engineering Abstracts; W.P.R.—Water Pollution Research (British); I.M —Institute of Metals (British).*

WARTIME WATER WORKS PROBLEMS

State of Washington Plans Water Works Defense. Anon. Am. City. **57:** 3: 40 (Mar. '42). To prepare water works depts. to meet air attacks and sabotage of their property, Wash. State Dept. Health has distributed bul. which contains: inventory and description of all chlorinators in state; recommendations concerning fencing, flood-lighting and patroling of intakes, dams, pumping stations, supply lines and reservoirs, and frequent emphasis on value of well-trained repair crews. Stresses protection plans which should be made against deliberate contamn. of supply since "it is known that dried typhoid organisms can be compressed so that one ton weighs only 100 lb." Permission will be granted by health dept. to cross-connect, temporarily, with private water supplies.—*F. J. Maier.*

Air Raid Precautions as Related to Building Design. S. D. Lash. Eng. Jour. (Can.) **25:** 28 (Jan. '42). Suggestions based particularly on Wartime Bldg. Bul. No. 10 of Dept. of Scientific and Industrial Research in Britain. Bldgs. should not be placed in close proximity to well-defined topographical features. Regular arrangement of bldgs. and roads should be avoided. Road surfaces should be dark, and hedges planted along sides. Bldgs. that are high, or have inclined roof glazing, or saw-tooth roof should be avoided, but roof should slope enough to provide rapid runoff to avoid reflections. It is possible to design single-story factory in which extensive collapse of roof unlikely even under direct hit from heavy bomb. Accomplished by bldg. structure with considerable degree of continuity. Collapse of series of roof trusses can be avoided by continuous beams at right angles to planes contg. roof trusses. Vertical glazing in walls, close to ground, liable to damage from misses. No window openings lower than 5′ to 6′ above ground. Need for fire protection clearly shown, degree depending on combustible contents of bldg. Even ½-hr. protection may be sufficient to prevent collapse. Fire protection methods include: adequate water supplies, automatic detecting and extinguishing systems, and self-closing doors and other barriers to spread of fire. Subdivision of floor space into comparatively small areas undesirable since blast effect may be increased. Provision of proper exit facilities of great importance. Second exit should be available from every floor area. Walls 3′ or 4′ high, subdividing floor areas useful in protection against splinters and will not confine blast effect sufficiently to increase structural damage.—*H. E. Babbitt.*

Static Water Tanks. Construction in Basements of Damaged Buildings. Anon. Surveyor. (Br.) **100:** 30 (July 25, '41). On sound, existing floors, where qual. and thickness of concrete are satisfactory,

$\frac{3}{4}''$ asphalt in two layers used, with skirting to walls. 6" x 6" 8-gage wire mesh used to internal angles at junctions of walls with each other and with floor. Special precautions taken to prevent flooding of adjoining basements. Arrangements made to provide some method of emptying tanks where serious leakage takes place and further work necessary. Tanks enclosed by open-boarded fences constructed of salvaged timber. Water-holding tank easily constructed on flat roof in common brick, lined with asphalt, forming simple fire-fighting weapon. Can be built to any size or shape in places not immediately accessible to fire brigade, but vulnerable to incendiary bomb. Fire council approved intensive program expending £4,000,000 for provision of supplementary water supplies for fire fighting.—*H. E. Babbitt.*

Water Supply in Air Raids. ANON. Eng. News-Rec. **128**: 192 (Jan. 29, '42). Extracts from recent issue of Glenfield Gazette published by Glenfield and Kennedy Ltd., Kilmarnoch, Scotland. Duplicate pumping equip. at remote sites invaluable and means for bypassing main reservoirs and filters in event of derangement of these facilities, combined with provision for sterilization with chlorine, essential. Availability of prime movers other than elec. motors also of great importance. Fire engines and trailer pumps frequently used for emergency pumping, as are diesel engine units, and air-lift pumps supplied with air from road compressors have been used to raise water from wells. Inter-connection of mains of importance in making available alternative routes for water. All valves should be maintained in working order and positions of all valves clearly indicated on surface. Considerable stocks of pipes and fittings should be maintd. at different points on system. Long lengths of steel pipe have been found particularly effective for re-establishment of broken mains. Basements of bldgs. which have become untenable have been converted into reserve water storage units by concreting to extent necessary to ensure structural stability and applying mastic asphalt to render them watertight. Carts carrying 1 or more 250-gal. tanks and fixed street tanks of 500-gal. capac., kept full by patrols, utilized for domestic supply when distr. temporarily failed or water suspected of contamn. When doubt exists as to water qual., chlorine used for sterilization and, as additional safeguard, consumers advised to boil water. After heavy raid, first step to check waste by closing valves. When ends of broken mains stopped, valves may be re-opened in some cases, but in others whole sections must be isolated. Sometimes, escaping water may be trapped in improvised sumps and used for fire fighting. Interchangeability of equip., particularly of fire hydrant accessories, hose couplings, etc., extremely important.—*R. E. Thompson.*

Mobile Chlorinator for Emergency Use. ANON. Engineering. (Br.) **153**: 5 (Jan. 2, '42). Apparatus intended for towing behind another vehicle. Equipment has overall length of 10', width of 6', and height of 5'7". Gross weight, including two chlorine cylinders, each holding 130 lb. of chlorine, is 2,150 lb. Operating unit includes a 5-hp. gasoline engine and pump capable of delivering 22 gpm. (Imp.) against head of 400'.—*H. E. Babbitt.*

Volume Water System Sales Encouraged by the Government. C. A. KUEBLER. Plumbg. & Heatg. J. **112**: 3: 45 (Mar. '42). Limitation order, L-26, with A-3 priority permits pump industry to mfr. pumps and water systems from Nov. 1, '41 to Nov. 1, '42, vol. totaling about equal to '40 production in terms of unit sales. Significantly indicates close and sympathetic consideration given water supply equip. by W.P.B. If demands for pumps and water systems from industry exceed L-26, shortage will exist over latter months of yr. If so, limitation order may be revised upward. Nov.–Dec. '41 shipments indicate present production rate about twice limitation order.—*Ralph E. Noble.*

Farm Water Systems Aid in Battle of Food. ANON. Plumbg. & Heatg. J. **112**: 1:44 (Jan. '42). Dept. of Agric. '42 farm program calls for largest production of food and food products in history.

Mechanization of farm water supply short cut to increased food production. Highest civilian priority rating, A-8, granted elec. farm water systems in recognition of importance of running water to above program.—*Ralph E. Noble.*

Tin Shortage Demands Thorough Trial of Available Substitute Solders. ANON. Lead. **12:** 2: 3 (Mar. '40). Tin essential metal of war; also essential ingredient of soft solders for many yr. War cut off from Am. principal source of tin supplies in Pacific. Govt. found it necessary to curtail drastically use of tin in many products. Solder mfrs. and users working diligently to find suitable substitute employing reduced amts. of tin or none at all. Deg. of success attained detd. only by actual use of new solders under operating conditions. Users, however, should give them every fair chance. Absolute necessity to reduce tin in solder to amt. permitted by govt.; patriotic duty to go even farther than govt. requires. Hardly expected that one new alloy or group of alloys can be quickly developed to replace std. tin-lead combinations of past. Quite possible, however, that no. of new alloys can be developed, each proving suitable substitute for certain soldering operations. May even be necessary to adapt soldering methods slightly to new alloys. Tin-free solders contg. small percentages of silver and balance lead now available. Users report finding these alloys satisfactory for certain kinds of soldering but have had to modify methods somewhat. Considerably higher melting point than most tin-lead solders, but often no disadvantage other than to require hotter irons or higher temps. Sometimes higher melting point even advantageous. Cannot, of course, be very successfully used to join low-melting metals like lead, and plastic range limited. Another group consists of various combinations of lead, tin, bismuth, silver and sometimes antimony, tin content being low. Group has much lower melting point than lead-silver group and reasonable plastic range. Reports indicate they can be employed successfully for no. of purposes. In some cases, too, solder mfrs. report much lower tin content solders proving satisfactory for some purposes where higher tin content formerly thought necessary. Alloy of lead with only about 10% tin and small amts. phosphorus and other addns. being used for dip soldering operations and for tinning copper. Study of

COMPOSITION, % BY WT.					LIQUIDUS	SOLIDUS	TENSILE STRENGTH	BOND STRENGTH OF LAPPED JOINTS	SPREAD OF ½ GRAM
Sn	Pb	Ag	Bi	Sb					
					°C.	°C.	psi.	psi.	sq.in.
40	60	—	—	—	238	183	5,660	6,270	1.30
—	97.5	2.5	—	—	304	304	4,980	3,740	0.19
—	95	5	—	—	375	304	4,915	4,340	0.20
10	90	—	—	—	298	183	4,850	4,960	0.27
10	87.75	2.25	—	—	290*	—	4,950	5,000	0.41
20	80	—	—	—	275	183	4,940	5,680	0.37
20	78	2	—	—	267*	—	5,620	5,550	0.57
30	70	—	—	—	257	183	5,390	5,770	0.83
30	69	1	—	—	251*	—	8,810	5,620	0.86
15	78.5	1.5	5	—	264*	—	4,960	5,310	0.47
15	77.5	1.5	5	1	258*	—	8,000	5,090	0.29
20	74.85	1.5	3	0.5	258*	—	8,120	5,380	0.39

NOTE: Bond and spread tests made on copper sheet. Tensile tests made on chill cast strips of the alloys. Conventional 40-60 tin-lead solder included for comparison.
* Detd. from cooling curves; other temps. from literature.

fluxes just as important as study of solder alloys. Will be found that some new solders require different fluxes. Therefore, in trying out new solder compositions, different fluxes should also be tried if those formerly used not satisfactory. Solder users may also, by close examn. of operations, be able to reduce amt. of solder used per joint and, in some cases, no. of joints. May be possible to substitute other methods of joining for soldering during duration, even though this may increase cost or prove somewhat less satisfactory. Since no one solution to all soldering problems, co-operation between mfrs. and users of solder appears essential so that war aims of country may be advanced. Table (from *Metals & Alloys*, Mar. '42) lists some of solders mentioned and gives some of properties they are reported to possess.—*Ed.*

Water Softener Aids in Metal Conservation. ANON. Plumbg. and Heatg. J. **112:** 2: 46 (Feb. '42). By preventing scale formation on inside of water heater coils, water softeners conserve copper, now near top of vital war materials list. Hitherto customary to replace coils when scale deposits impede flow. Water softener confers further advantages of cutting soap costs in half and facilitating household activities involving water use.—*Ralph E. Noble.*

Ways to Get More Wartime Power. ANON. Food Ind. **14:** 2: 44 (Feb. '42). Ever-increasing demands of war industries and possibility that sabotage or bombing of power plants will cut power supply, threaten power shortage. Timely to consider installing emergency or stand-by power units. Diesel engines economical for purpose, operate at low fuel cost and lend selves to utilization of waste heat from cooling water and exhaust. Several installations in food industries illustrated. Gas engines efficient in localities where natural gas available at low cost. Gasoline engines may be used in special cases. With ingenuity, may harness used automobile engines. Fuel for these relatively expensive, but in wartime emergency, economy comes second to production.—*Ralph E. Noble.*

Bases of Sewage Plant Design for Army Cantonments. ANON. Sew. Wks. Eng. **13:** 71 (Feb. '42). Designs provide for following factors with indicated limits: *Sewage quants.* Avg. 70, max. for several hr. 140, peak 210 gpd. *Sewage characteristics.* Suspended solids 460, B.O.D. 290, ether soluble 150 ppm. *Measuring devices.* Include Parshall or Palmer-Bowlus (rectangular) flumes, Venturi meter if it fits force main on pumping sta. discharge and weir. *Grit chambers.* Omitted except in special circumstances. Generally hand cleaned, screenings buried. *Bar screens.* Clear space 1" x 1½", hand or mech. cleaned, screenings buried or burned. *Primary sedimentation tanks.* Displacement period based on avg. flow; sedimentation only or ahead of trickling filters; in high diln, settled sewage, 2.5 hr.; ahead of activated sludge, avg. flow 3 hr.; ahead of bio-filters, avg. flow 1.5 hr., (1) for diln. ratio 1:1.5, generally with single filtration, 7.5 hr., (2) for ratio 1:1, generally with 2-stage filtration, 6 hr. *Trickling filters.* (1) Std., or low-grade, in southern locations, no severe winter—not to exceed 5,000 pop. per acre-ft. With 6' deep filters, this is 2.1 mgd. avg. at 70 gpd. per capita. In northern climates, loadings should not exceed 4,000 pop. per acre-ft. (2) In south, high-rate trickling filters to have loads not exceeding some 3,000 lb. B.O.D. applied per acre-ft. Equiv. to 35,000 pop. per acre-ft. In north, should not exceed 30,000. *Final sedimentation tanks.* Flow not to exceed 800 gal./sq.ft./24 hr., and not <2.25 hr. displacement, both based on avg. actual flow through tank. Depth 10–12' with some reduction or increase in special cases. *Sludge digestion tanks.* Trickling filter type for primary and secondary sedimentation and heated sludge tanks, 2.3 cu.ft. per capita; for unheated sludge tanks, warm climates, add 25–50% to foregoing; large capacs. in locations close to occupied bldgs.; for activated sludge type, increase by 50%. *Sludge drying beds or lagoons.* In warm climates and suitable locations, drying sludge in lagoons minus underdrains or filter material, acceptable with 2–3 sq.ft. per capita; sludge drying beds

with underdrains and filter material also acceptable; for trickling filter type, provide 0.5–1.0; for activated sludge type, 1.0–1.5; lower unit applies to most favorable conditions with opportunity for lagooning excess sludge. *Imhoff tanks.* Sedimentation compartment same as primary sedimentation tanks and digestion compartment same as for unheated separate sludge digestion tanks; in northern climates, use for sludge compartment of Imhoff tanks; with plain sedimentation, 2.0–2.5 cu.ft. per capita; with same plus trickling filters, 3.0–3.5.—*Ralph E. Noble.*

Advisory Committee on Scientific Publications. FRANK B. JEWETT, ROSS G. HARRISON AND LUTHER P. EISENHART. Science. **95:** 166 (Feb. 13, '42). Substance of manuscripts or abstracts for publication might inadvertently become of aid to our enemies. Natl. Acad. of Sciences and Natl. Research Council organized Advisory Com. to deal with problem. Com. ready to advise with editors of journals and secretaries of societies about procedure to follow in such cases. If postponement of publication advisable, author and editor so informed. When published, accompanying note will indicate date received and fact publication withheld on acct. of war emergency. Means delay in some cases; facilitation in others, where author uncertain of military value of text.—*Ralph E. Noble.*

The Australian National Research Council (A.N.R.C.). ANON. Science. **95:** 279 (Mar. 13, '42). In Oct. '40, A.N.R.C. proposed to prime minister, at his request, Scientific Advisory Com. along lines of Hankey Com. in Britain and President's Scientific Advisory Com. in U.S. Proposal unacceptable but alternate arrangement approved whereby A.N.R.C. to maint. close contact with executive of Council for Scientific and Ind. Research (C.S.I.R.) through special representative. Arrangement to be reviewed after 12 mo As result of past year's experience, executive com. requested Commonwealth Govt. to authorize 2 men, versed in knowledge of ind. and science, to spend 3 mo. examg. situation by consultation with leaders in ind. and other war activities. These would submit to prime minister proposals for increasing effective use of country's scientific resources. Proposal first discussed fully with C.S.I.R., which agreed to support A.N.R.C. In past 12 mo., executive com. established contact between A.N.R.C. and 11 official agencies. As result, several scientific problems arising from nation's war effort dealt with by scientists in universities and elsewhere. Projects cited.—*Ralph E. Noble.*

IMPOUNDING RESERVOIRS

Bituminous Surfacing Treatment of Portion of the Water Supply Catchment at Narrogin, Western Australia. J. W. YOUNG. Civ. Eng. (Br.) **36:** 548 (Aug. '41). For some years past, Public Works Dept. of Western Australia has been investigating means of providing artificial catchments for areas of light rainfall and small runoff. In June '35, ¼-acre plot cleaned, ploughed, all roots and grass raked out, soil rolled with hand roller, and ½-gal. (Imp.) per sq. yd. of fuel oil applied to prevent germination of seed. Emulsified bitumen, ⅓ gal. (Imp.) per sq.yd., and sand then applied to secure impervious surface. After 4 yr. condition excellent and work extended to area of 50 acres. Two principal methods possible: (1) spraying oil and emulsion by means of small sand sprays from drums; (2) spraying by means of large mech. sprayers. To secure finished bituminous surfaced catchment, necessary to: clear area, plough and harrow, stabilize light soil with clay, consolidate soil by rolling under both dry and moist conditions, apply fuel oil at ⅓ gal. (Imp.) per sq.yd., provide light impervious surface of emulsified bitumen and sand (0.4 gal. (Imp.) per sq.yd. placed in two applications), and provide necessary drains to discharge water into reservoir. Area selected for treatment estd. to promote

flow of 18 to 20 mil.gal. (Imp.) annually into reservoir. Area of 2 acres isolated for recording purposes, and to provide information regarding runoff under very light rainfall, and loss of eff. over the years. Ordinary, commercial fuel oil used. Because of sloping ground, however, oil could not be sprayed in one application, necessitating two sprayings of $\frac{1}{4}$ gal. (Imp.) per sq.yd. each. Before application of second coat, excess sand from first coat swept up for better results and because of dustiness of sand. Removal of excess sand from final surface increased eff. of catchment, especially under light showers. On exptl. area from which excess sand was not removed water did not commence to flow appreciably from outlet until 7 points of rain had fallen; on swept surface of new work, water commenced to run when 2 points of rain had fallen.—*H. E. Babbitt.*

Solving Reservoir Problems With Circular Point-by-Point Computer. J. M. SHEPLEY AND C. B. WALTON. Civ. Eng. **12:** 154 (Mar. '42). For solution of many reservoir and allied problems authors have developed simple and inexpensive instrument patterned after circular slide rule. Useful for such problems as routing flood waves through reservoirs with orifice or weir-type outlets; detg. size of spillway required to pass "design flood" without reservoir level exceeding given el.; finding amt. of prime power available from hydroelec. project as detd. by lowest seasonal flow and available reservoir storage; computing energy available from tidal power plants; placing hydroelec. plants which have seasonal storage on large system loads in order to obtain max. dependable capacity from equip.; and routing power waves down rivers. Advantages which instrument offers in solution of such problems, especially when of extensive nature, are ease and rapidity of obtaining answers, consistency and accuracy of results, flexibility of changing boundary conditions in computations, and securing of permanent working charts for operation of project. Instrument consists of 2 celluloid index arms mounted on circular percentage-protractor, so that each arm and protractor is free to move relative to the other, and a work board. To facilitate dwg. of concentric circles with center of protractor as their centers, and to enable angular distances to be marked off along these circles, holes drilled along index line, on index arm. Screw assembly fastening index arms to protractor such as to act as center guide and punch for paper mounted on work board over center guide hole.—*H. E. Babbitt.*

A Method of Estimating the Maximum Possible Silt Deposit Upstream of Dams Constructed in Silt-Carrying Rivers. ABDEL AZIZ AHMED. Wtr. & Wtr. Eng. (Br.) **43:** 288 (Oct. '41). Natural silt-carrying rivers are, to certain extent, self-correcting in matter of silting and scour; periodic changes give rise to alternate silting and scouring until critical velocities attained at all points. Assumption appears to be justifiable in respect to Nile, as several dams have caused no appreciable alteration of river bed. Max. quant. of silt deposited or scoured, theoretically equal to change in water content of stretch of river caused by raising or lowering water level. In table are shown max. amts. of silt deposit corresponding to given water levels in [Aswan] reservoir, together with resulting percentage reduction in capac., equal to 5,600 cu.m. when filled to reservoir level (R.L.) 122.

RESERVOIR LEVEL, IN M.	WATER CONTENT, CU.M. $\times 10^6$	MAX. SILT DEPOSIT, CU.M. $\times 10^6$	REDUCTION IN RESERVOIR CAPAC. IN %
98			
100	62	62	1.8
101	105	105	1.9
102	165	165	2.95
103	230	230	4.1
104	300	300	5.35
105	390	390	7.0

By reservoir capac. is meant storage capac. of reservoir above natural river discharge.—*H. E. Babbitt.*

Removing Reservoir Silt by Sluicing Operations. ANON. Eng. News-Rec. **127:** 20 (July 3, '41). Upper San Fernando Reservoir of Los Angeles Bureau of Water Works & Supply has drainage area of 5,430 acres, 80% being covered with brush growth and remainder under cultivation. After about 20 yr. service, original capac. of 1,977 acre-ft. reduced by silt to about 1,500' acre-ft., 24% decrease. Particularly heavy deposition occurred during flood of Mar. '38, estd. turbidity at that time being greater than 500 ppm. After storm, soundings indicated deposition totaled 20' around intake tower and over most of lower portions of reservoir. An 8" pipe installed for sluicing operations, hose diams. being 2½" and 4", nozzles ¾" and 1¼" and pressure 75–120 psi., depending on no. of nozzles used. Top 5' of deposit very soft, while bottom 15' very dense clayey material. Flow of 10 sec.-ft. running through reservoir from upper end created meandering channel and removed considerable amt. of silt without sluicing. Reservoir kept unwatered for 38 days, during which time about 20,000 cu.yd. of sediment removed with expenditure of 220 man-days, avg. of 90 cu.yd. per man-day. Actual sluicing not considered to have netted more than 50 cu.yd. per man-day. Debris disposed of at extreme upper end of Lower San Fernando Reservoir, which is near base of Upper San Fernando Dam. Earthfill dam 450' long and contg. some 17,000 cu.yd. built creating debris basin of 20,000-cu.yd. capacity. Small overflow pipes allowed water to escape into Lower San Fernando Reservoir. Believed that soft material could be removed by small stream meandering across unwatered reservoir bottom, employing sluicing only for creating new channels and changing course of stream. Large storm channel built around both reservoirs to prevent entry of storm water heavily laden with debris.—*R. E. Thompson.*

Sediments of Fresh-Water Lakes. W. H. TWENHOFEL AND V. E. MCKELVEY. Bul. Am. Assn. Petrol. Geol. **25:** 826 ('41). Environmental factors controlling sedimentation in lakes, and plan of and characteristics of deposits described. Deposits of different lakes have individual characteristics. Rates of deposition vary with lakes. Deposits over deep part of almost every lake have high content of matter of org. origin. After deposition, org. matter eliminated and carbonates increase or decrease. Much formation of combustible gas. Paraffin wax extracted. Bacteria and other micro-organisms responsible for these changes.—*C.A.*

Oxidation-Reduction Potentials and pH of Lake Waters and of Lake Sediments. R. J. ALLGEIER, B. C. HAFFORD AND C. JUDAY. Trans. Wis. Acad. Sci. **33:** 115 ('41). Characteristics in question of waters of 3 oligotrophic, 6 eutrophic and 2 dystrophic lakes in northeastern Wis. detd. *in situ*. Graphical data [variations are wide] given for E_H, pH, D.O., ferrous iron, hydrogen sulfide and temp. at different depths. E_H values of surface waters ranged from +0.38 to +0.5 v., those of bottom waters +0.057 to +0.444, and those of bottom sediments −0.14 to +0.2. D.O. not only factor involved in decreasing reduction-oxidation potential of lower water; ferrous iron and hydrogen sulfide evidently play part and probably org. reducing systems as well. No decrease, or at most only small one, in reduction-oxidation potential of lower water of oligotrophic lakes found; much greater in lower waters of 2 other types of lakes. That reduction-oxidation potentials of lakes controlled by dynamic factors rather than by static agents shown by fact that the 7 lakes on which 2 sets of observations were made about 1 mo. apart showed marked differences on 2 dates.—*C.A.*

Observations on Temperature, Hydrogen-Ion Concentration and Periods of Stagnation and Overturning in Lakes and Reservoirs of San Diego County, California. GEO. F. MCEWEN. Bul. Scripps Inst. Oceanog. Univ. Calif. **4:** 219 ('41). Subtropical lakes develop temp. stratification during summer. Stability of lake closely related to temp. gradient and reaches max. in Aug. for lakes studied. Turnover occurs in winter when stability low. pH increases in surface

layer and decreases in bottom layer from winter to summer, giving rise to steep gradient through thermocline. Steady wind velocities of 30 mph. or more required to cause turnover in shallow Sweetwater L. during May to Oct. In deeper Murray L., this velocity would not cause turnover until middle of Dec. Arithmetical method for calcg. lake stability given.—*C.A.*

The Change of Composition of Drinking Water on Storage. F. M. BORISHANSKAYA. Lab. Prakt. (U.S.S.R.) **16:** 4: 18 ('41). Well water kept in 500-ml. stoppered flasks at 0°, 10° and 20°, and anald. after 1, 24, 48 and 72 hr. Changes in pH between wide limits, but without regularity, observed. NH_3 remained unchanged. Nitrites and nitrates changed little and without regularity in connection with time and temp. of storing. No appreciable changes in abs. and relative amts. of inorg. N.—*C.A.*

Limnological Investigation on Texas Reservoir Lakes. J. B. HARRIS AND J. K. G. SILVEY. Ecol. Monog. **10:** 111 ('40). Study of series of artificial reservoirs in Tex. made in attempt to correlate phys. chem. and biol. composition of water with aging of reservoirs. Reservoirs Bridgeport, Eagle Mt., Lake Worth, and Lake Dallas examd. Data given showing seasonal variation in vertical distr. of temp., turbidity, pH value, and concns. of D.O., nitrogen, free carbon dioxide, alky., phosphates, and chlorides. List given of higher aquatic plants in each lake. Monthly variation and vertical distr. of plankton in different lakes compared. From study, appears that age of lake only one of many factors affecting biol. productivity. Older lakes appear to be as productive limnologically as those of more recent formation, and in some cases more productive. Further investigations in progress.—*W.P.R.*

Investigations of New Water Supply of Ankara From the Çubuk Reservoir. I. M. Vranyale. Türk Hıfzıssıhha Tecrübî Biyol. Mecmuasi. **1:** 2: 85 ('39); Zbl. Ges. Hyg. (Ger.) **47:** 197 ('40). Reservoir at Çubuk, serving Ankara, has capac. of about 13,000,000 cu.m. Gathering ground uninhabited and protected from poln. As no. of bacteria in water increase, after rain, etc., water treated with aluminum sulfate, passed through rapid filters and chlorinated. Results of chem. and bact. anals. shown. —*W.P.R.*

The Chlorophyll Content and Productivity of Some Lakes in Northeastern Wisconsin. WINSTON M. MANNING AND RICHARD E. JUDAY. Trans. Wis. Acad. Sci. **33:** 363 ('41). With certain limitations, chlorophyll may be used as index of photosynthetic capac. of epilimnion waters. At optimal light intensity, avg. capac. found to be 7 mg. oxygen produced per mg. of chlorophyll per hr. This corresponds to reduction of 1 molecule CO_2 by 1 molecule of chlorophyll every 18 sec. Approx. productivities, in terms of glucose calcd. for 7 lakes from chlorophyll and photosynthesis data. With clear Aug. day as basis of calcns., highest calcd. productivity of group studied was 44 kg. glucose per ha. per day, figure far short of theoretical max. production (430) of culture of green alga *Chlorella*. Lowest value found, 14 kg.—*C.A.*

The Surface Tension of Wisconsin Lake Waters. YVETTE HARDMAN. Trans. Wis. Acad. Sci. **33:** 395 ('41). Data correlated with lake classification according to productivity. Range of surface tension depressions, in dynes/cm., found in various situations are: oligotrophic lakes, 0–2; eutrophic lakes, 0–20; bog lakes, 0–20; lakes with foam, 2–9; near Lemma and lilies, 5–20; during plankton bloom, 0–20. Presence of such surface films as detected by method used depended most often upon biol. activity and sometimes upon dissolved org. matter of water. Possible ecological signif. of these films mentioned.—*C.A.*

Manganese in Deep Reservoirs. EDWARD S. HOPKINS AND GEORGE B. MCCALL. Ind. Eng. Chem. **33:** 1491 (Dec. '41). Data published '31 indicated seasonal presence of soluble Mn in deep reservoir water due to its soln. as bicarbonate. Material dissolved by relatively large concn. of CO_2 in water.

10-yr. investigation shows silting will not overcome phenomenon. Newly deposited muck will perpetuate trouble because of large amt. of decomposing Mn-bearing vegetation. Mn content at bottom of deep reservoir practically const. perennially, while content in shallow one affected by seasonal "turnover." As Mn removal is coagulation problem in conjunction with water purif. plant operation, isoelectric point of manganese hydroxide detd.—*Ralph E. Noble.*

Ridding Reservoirs of Floating Logs. ANON. Eng. News-Rec. **128:** 420 (Mar. 12, '42). When accumulation of flotsam had increased until it covered about ¼ of area submerged at high-water stage, contract was let by Tacoma for removing debris from reservoir in heavily wooded area which had not been cleared before flooding. Found that best method of removing logs is to work in season of high water when everything that will float is on surface. Winds usually drive material to one end of reservoir, where logs can be handled with pike pole by 1 man on log-boom at rate more than equal to speed of donkey-engine crew at low-water stage, attempting to drag logs overland to burning pile. Burning most economical means of disposal. Chain conveyer rig used for lifting logs from pond into sawmill works very well for taking drift from reservoir and discharging it over side-dump platform to burning pile. Latter can be fed and kept burning fiercely with logs just pulled from water. Floating drag-saw used to cut logs which were too long for side-dump platform. Logs too large for chain conveyor diverted into boomed enclosure, whence they could be pulled together by donkey engine for burning at low-water stages. Acre of floating logs disposed of during each 8-hr. shift.—*R. E. Thompson.*

Experiments With Pond Muds. E. M. LIND. J. Ecol. **28:** 484 ('40). Describes study on interchanges which take place between mud on bottom of ponds and water at surface of mud; investigation made in attempt to correlate periodicity of algae with climatic conditions and with changes in chem. compn. of water. Samples of mud collected from 3 ponds: one, in moorland area, had peaty bottom and water had pH value of 6.4 to 6.8; second, on coal measures, contd. black org. mud and water had pH of 7.2 to 8.0; third, on magnesium limestone, contd. calcareous mud and water had pH of 8 to 8.6. Expts. lasting 6 wk. made in large glass jars each contg. 1½" mud and 1½ l. water. In one series all leaf mold and twigs removed; layer of leaf mold added to second series after mud settled. In third series conditions made relatively anaerobic by placing thin layer of paraffin on surface of water. Jars kept in north window of cool room and water drawn off fortnightly from one jar in each series for anal. During first 2 wk. of expt., concn. of nitrate in water decreased in all cases; since demonstrated that oxidizing conditions maintd. throughout expt., decrease could not have been due to denitrifying bacteria. If, however, nitrate adsorbed into deeper anaerobic layers of mud, might be reduced to gaseous nitrogen and lost. Decrease in nitrate accompanied by increase in concn. of ammonia caused by decompn. of org. material; this increase more pronounced in jars contg. leaf mold. Higher content of ammonia maintd. after 2 wk. in jars contg. mud from moorland lake but declined rapidly in other jars due to either oxidation or adsorption by mud. Carbonate hardness, concn. of iron, and pH value varied according to ammonia available to replace cations in mud. Concn. of phosphate highest in jars contg. leaf mold. Jars contg. similar samples of mud and water kept in sunny window and growth of algae noted; growth highest in all cases after 6 wk., and was often greater under anaerobic than under aerobic conditions. At end of expt. water covered with paraffin still half satd. with oxygen. Concn. of inorg. nitrogen, however, was very low. Algae continued to grow when no nitrate or ammonia could be detected. Mud from moorland pond most productive and mud from pond on coal measures least. Appears that reactions at surface of mud include decompn. of org. matter, with liberation of ammonia and nitrates, and absorption

of ammonia by mud particles with liberation of exchangeable bases. Balance between these reactions, amt. of available oxygen, and temp. are factors which probably affect germination and amts. of inorg. nitrogen and soluble bases liberated into water will affect growth of algae after germination.—*W.P.R.*

ALGAE CONTROL

A Method of Maintaining the Proper Copper Concentration in the Treatment of Water. O. R. SWEENEY. Proc. Iowa Acad. Sci. **48:** 259 ('41). Excess of satd. soln. of $CuSO_4$ added, with stirring, to Na_2SiO_3. Light-blue ppt. which readily settled out formed. Compd. much less soluble than metallic Cu. $CuSiO_3$ compd. and metallic Cu offer interesting possibilities in algae control. Metallic Cu when in water for 72 hr. or longer will produce Cu concn. in water sufficient to kill practically any alga. Where lower concn., under similar conditions, desired, $CuSiO_3$ compd. may be used. In many cases, water will not remain in contact with Cu material long enough to build up max concn. of Cu ions. Neither will this in all cases be necessary. Many algae, for example, killed by concn. of 0.25 ppm. produced by a 1-hr. contact with $CuSiO_3$ material. Such concn. not toxic to some fish, such as perch, sunfish and black bass, although toxic to trout, carp and catfish. Even lower concns. should prevent growth though not sufficient actually to kill algae already growing vigorously. Not as much Cu should be necessary in running water as in still water, since most of algae do not grow readily in running water. May be possible automatically to regulate amt. of Cu necessary to prevent algal growth by allowing water to flow over Cu or $CuSiO_3$ material as it passes into storage reservoir. Material could, for example, be suspended from floats anchored in water. Conc. of Cu in water would vary with rate of flow, thus more or less adjusting it to need. Since concns. less than 20 ppm. of Cu in water considered harmless, if not beneficial to human beings, water treated in this way potable.—*C.A.*

Aerotreatment of Water Reservoirs With Copper Sulfate. B. M. YASNOV AND P. A. DORFMAN. Vodos. Sanit. Tekh. (U.S.S.R.) **16:** 1: 15 ('41). Most phytoplankton distributed in epilimnion, down to 1–1.5 m. from surface. Sprinkling of surface with powd. $CuSO_4$ from airplane effective, economical. Carried out in quiet early morning hours. *Microcystis aeruginosa*, *Coelosphaerium* and *Anabaena* completely absent on third day, from 28,000,000, 10,600 and 13,000 respectively, after surface treatment with 0.51 g. per cu.m., equiv. to 0.182 g. per cu.m. on total vol. of water.—*C.A.*

Effect of Copper on Algae. K. A. GUSEVA. Microbiol. (U.S.S.R.) **9:** 480 (*in English*, 490) ('40). Copper more toxic to algae than manganese. Protococcus group of algae most resistant, blue-green algae most sensitive, to copper poisoning. Copper does not definitely accelerate growth of algae as does manganese. Masses of dead plankton increase amt. of nitrogen-contg. org. matter, furthering growth of nitrophilic (copper-resistant) algae. Org. matter utilized at rate of its accumulation. —*C.A.*

Copper Sulfate and Rotenone as Fish Poisons. M. W. SMITH. Trans. Am. Fish. Soc. **69:** 141 ('39). Describes expts. on destruction of fish in lakes in Nova Scotia preparatory to stocking with trout. Toxicity of copper sulfate to fish varies with species, temp. and hardness of water, and content of org. matter. Concn. of 3 ppm. copper sulfate proved effective for killing fish, though some eels (*Anguilla rostrata*) and some killifish (*Fundulus diaphanus*) survived. Most of plankton and bottom fauna destroyed, but higher plants such as *Nymphaea*, *Juncus*, etc., not affected. Algal pops. almost entirely destroyed. About a year before plankton and aquatic insect larvae and nymphs repopulated lakes; molluscs did not reappear. Much of copper apparently removed from soln. in acid waters by combination with org. matter. Considerable quant. of copper remains in water for some time, but much probably combined and not in toxic ionic form. In expts. on toxicity of rotenone, derris

and cubé powders contg. 5% rotenone, in concn. of 0.2 ppm. at 5° and 20°C., killed yearling trout. When applied to small acid lake 0.25 ppm. of derris contg. 5% rotenone killed most fish, though a few eels, lake chubs, and sticklebacks survived. Storage of derris and cubé powders in dry conditions for 3 yr. did not affect their toxicity. Toxic action of rotenone increased with increasing temp. Concns. of rotenone sufficient to kill fish destroyed Crustacea and may have affected some amphipods, but other forms of plant and animal life appeared to be unaffected under natural conditions. Caddis larvae were killed by prolonged exposure to 0.5 and 1.0 ppm. derris under exptl. conditions. After small lake had been treated with 1.33 ppm. derris, water remained toxic to fish for about 1 mo.—*W.P.R.*

Algicides. THOMAS S. CARSWELL AND HOWARD K. NASON (to Monsanto Chemical Co.). U. S. Pat. 2,253,762 (Aug. 26 '41). Compn. adapted for control of algae, protozoa and slime growth prepd. with use of 2,4,5-trichlorophenol or other halogenated water-sol. monocyclic phenol contg. at least 3 halogen atoms in mol., at least 2 of which are in adjacent positions on benzene nucleus.—*C.A.*

Sodium Pentachlorophenate Treatment for Cooling Water. MAX GELFORD. Power Plant Eng. **45:** 60 (May '41). C_6Cl_5ONa effective in preventing and destroying algae growth. Not broken down or decompd. at 212°F. over several days' time. CO_2 absorption seems to have no effect, and corrosion decreased rather than increased. Comparative costs with chlorine given. Writer prefers it to Cl.—*C.A.*

Silicon and Phosphorus as Factors Limiting Development of Diatoms. A. C. GARDINER. J. Soc. Chem. Ind. (Br.) **60:** 73 ('41). Shown that although end of spring max. of diatoms in unused reservoir appeared to be due to exhaustion of dissolved silicon and phosphorus in water, nos. of diatoms did not increase again when concns. of these elements increased. As nos. of some species decrease before those of others, other factors besides available supplies of silicon and phosphorus must be involved. Before relations between nos. of diatoms and content of silica can be detd., necessary to know rate of return of silicon to circulation from bottom mud, and natural rate of mortality of diatoms. Gross production of diatoms may be estd. from knowledge of variations in their nos., and of rate of depletion of silicon in water.—*W.P.R.*

The "Blooming" of Water and Method of Predicting the Condition. K. A. MUDRETSOVA AND B. S. ALEEV. Vodos Sanit. Tekh. (U.S.S.R.) **14:** 3: 17 ('39); Chem. Zentr. (U.S.S.R.) **II:** 4049 ('39). Abundant plankton growth in water undesirable from standpoint of both taste and health and causes stoppage of mains. Method of Schreiber, as modified by Gussewa, for predicting behavior of water in this respect as follows: To 7 of 8 samples of water add: (1) N as $Ca(NO_3)_2$; (2) P as KH_2PO_4; (3) Fe as $Fe_2(SO_4)_3$; (4) N + P; (5) N + Fe; (6) Fe + P; and (7) N + P + Fe, elements being added in form first given. Stopper samples with cotton. plugs and place in thermostat. After 4–5 days det. plankton content by counting. Results make it possible to det. whether abundant plankton growth to be expected and also indicate to what extent growth is favored by substances tested.—*C.A.*

The Ecology of a Temple Tank Containing a Permanent Bloom of *Microcystis aeruginosa* (Kutz.) Henfr. S. V. GANAPATI. J. Bombay Nat. Hist. Soc. (India) **42:** 65 ('40). Absence of water movement, high temp. and high content of org. matter and phosphate in water appeared to be most important factors favoring development of *M. aeruginosa*. Nitrites and nitrates absent. Dissolved gases appeared to have no influence. Nutrient substances required for growth of alga brought up daily to surface from bottom, where dead algal cells decomposed by bact. action.—*C.A.*

Vertical Distribution of the Plankton Rotifera in Douglas Lake, Michigan, With Special Reference to Submerged Depression Individuality. ROBERT S. CAMPBELL. Ecol. Monographs. **11:** 1 ('41). Pop. concn. zones occurred in regions of rapid oxygen decline, and

Rotifera usually absent from strata devoid of oxygen. Numerical decrease usually marked in transition zone between stratum with rapid oxygen decline and stratum devoid of oxygen. Rotifer distr. appeared to be closely related to oxygen, carbon dioxide and pH changes. Little or no distributional change occurred within thermoclines, save late in summer when apparently oxygen conditions forced concn. zones within thermoclines. Differences in rotifer distr. among depressions appeared to be related to chem. differences among depressions on corresponding dates. No evidence of alky. stratification coinciding with zones of fluctuation in rotifer pop. pH of surface waters normally varies around 8.2, while that of bottom waters only occasionally falls as low as 6.8.—*C.A.*

Limnological Studies of Western Lake Erie. DAVID C. CHANDLER. *I. Plankton and Certain Physical-Chemical Data of the Bass Islands Region. From Sept. 1938 to Nov. 1939.* Ohio J. Sci. **40:** 291 ('40). (*Abstracted,* Jour. A.W.W.A. **33:** 1297 ('41). *II. Light Penetration and Its Relation to Turbidity.* Ecology. **23:** 41 (Jan. '42). Daylight penetration into western L. Erie water measured with Weston photronic cell several times monthly from Sept. '39 to Nov. '40. 1% surface light depth penetration varied from max. of 9.7 m. with turbidity 5 ppm., to min. of 0.8 m. with turbidity 115 ppm. Greatest percentage surface light reaching 1 m. depth was 10.8 times greater than least; 2 m. depth, 86.6 times. Difference between greatest and least values for each of these depths due to difference in turbidity, not to nature of light reaching water surface. Greatest light loss in first 1 m. occurred within first 10 cm., varying from 13 to 49% of surface light. Turbidity, varying from 5 to 230 ppm., due primarily to material from bottom sediments, quant. of inorg. component being greater than org. Turbidity fluctuation not limited to season but changes weekly with meteorological conditions. Light transmission by these waters highest during winter, spring and early summer; lowest in late summer and autumn; most uniform vertically when storm conditions prevail; least so when relatively calm conditions follow stormy periods. In western L. Erie, 40 cm. ice-cover obstructed light penetration no farther than 40 cm. of water having 20 ppm. or greater turbidity. Biologically, turbidity and its variations in that area may influence: (1) composition, size, duration and time occurrence of phytoplankton pulses; (2) photosynthesis rate at various depths; (3) compensation point position of higher aquatic plants and phytoplankters; (4) vertical distr. of microcrustacea; and (5) magnitude of commercial catch of saugers (*Stizostedion canadense*). Turbidity and transparency detns. made with Secchi's disc. Temp. and standing crop of phytoplankton measured by methods described in Part I of report. *III. Phytoplankton and Physical-Chemical Data From Nov. 1939 to Nov. 1940.* Ohio J. Sci. **42:** 24 (Jan. '42). Yr.-round limnological data based on weekly observations of phytoplankton and general phys.-chem. factors of western L. Erie presented. Latter factors, excluding turbidity and ice-cover, similar to those for corresponding times in preceding yr. Ice-cover of '40 thicker and covered much larger area than before. Turbidity varied from 5 to 60 ppm.; highest in summer and autumn, lowest in winter and spring. In previous yr., highest in spring and autumn, lowest in winter and summer. Spring phytoplankton pulse with max. of 374,000 units/l. occurred from Mar. 14 to May 28. Diatoms composed about 98%. Genera most abundant were *Synedra, Asterionella, Fragilaria, Tabellaria* and *Melosira*. Autumn pulse occurred in 2 parts separated by 3 wk. Diatoms composed 77%. Genera most abundant were *Melosira, Stephanodiscus* and *Cylcotella*. Green and blue-green algae composed 23% of entire autumn pulse, 2% of spring pulse. Weekly observations indicate avg. turbidity of western L. Erie water is 25 ppm. or greater preceding and during phytoplankton pulse, latter small and of short duration. When avg. is 20 ppm. preceding and during pulse, latter large and of long duration. Diatoms compose greater percentage of total phytoplankton when avg. turbidity exceeds

25 ppm. than when $<$ 20 ppm. Conversely, green and blue-green algae compose greater percentage when avg. turbidity $<$ 20 than when $>$ 25 ppm. —*Ralph E. Noble.*

A Symposium on Hydrobiology. Univ. of Wisconsin Press, Madison, Wis. ('41) 405 pp. $3.50. Collection of 32 papers and abstracts of 16 others delivered at an institute held at the Univ. of Wis. in Autumn of '40. Represent wide scope of interests of present-day hydrobiology. Among them contributions dealing not only with biol. aspects of subject, but with environmental factors that affect aquatic life. Papers included are: Fragments of the History of Hydrobiology, James G. Needham; Human Culture Forms as Influenced by Lakes, Paul B. Sears; Lakes in Relation to Terrestrial Life Patterns, Aldo Leopold; Economic Phases of Riparian Land Use, George H. Twenhofel; Sedimentation in Artificial Lakes, Stafford C. Happ; Penetration and Scattering of Solar and Sky Radiation in Natural Water Bodies, Clinton L. Utterback; Dissolved Oxygen in Relation to Lake Types, Paul S. Welch; Rôle of Nitrogen and Phosphorus in Biochemical Oxygen Demand Dilution Water, William L. Lea; Aquatic Bacteria in Relation to the Cycle of Organic Matter in Lakes, Selman A. Waksman; Occurrence of Actinomycetes of the Genus Micromonospora in Inland Lakes, Wayne W. Umbreit and Elizabeth McCoy; Ecological Relations of the Larval Trematodes of Fresh-Water Snails, William W. Cort; Rôle of the Aquatic Fungi in Hydrobiology, William H. Weston; Limnological Rôle of the Higher Plants, Neil Hotchkiss; Photosynthesis of Algae and Other Aquatic Plants, George O. Burr; Relation of Hydrological Conditions to Speciation in Fishes, Carl L. Hubbs; Age and Growth of Fresh-Water Fishes, John Van Oosten; Fish Production of Inland Streams and Lakes, David H. Thompson; Management of Ponds for the Production of Game and Pan Fish, Homer S. Swingle and E. V. Smith; Pond Fish Farming in Poland, Stanislas F. Snieszko; Effects of Pollutional Wastes on Fish Life, Arch E. Cole; Gastro-Enteritis and Public Water Supplies, Charles R. Cox; Microbiology of Sewage and Sewage Treatment, Willem Rudolfs and H. Heukelekian; Quantitative Biochemical Relations in the Activated Sludge Process, Thomas R. Camp; Oxidation-Reduction Potentials in Activated Sludge, Gerard A. Rohlich, William B. Sarles and Lewis H. Kessler; Scientific Studies and Chemical Treatment of the Madison Lakes, Bernard Domogalla; Significance of Plankton in Relation to the Sanitary Condition of Streams, James B. Lackey; Food Economy of *Anopheles quadrimaculatus* and *A. crucians* Larvae, Charles E. Renn; Relation of Hydrobiology to Malaria Control, Lowell T. Coggeshall; Swimming Pool Sanitation: *Neisseria catarrhalis* as an Index of Pollution, George O. Tapley and Marshall W. Jennison; Schistosome Dermatitis and Its Distribution, Sterling Brackett; Methods Used in the Control of Schistosome Dermatitis in Michigan, Donald B. McMullen.—*Ed.*

TASTE AND ODOR CONTROL

Taste and Odor Control. L. C. Billings. Southwest W.W. Jour. **22**: 12: 17 ('41). Since basic study for cause of organic odors is biological life found in water, scientists at Dallas, Tex., plant, for past 2 yr., have been studying relation between odor and biological life. Though final conclusions have not been reached, evident that odor not due to any specific organism or organisms, but to dying of all org. life (in water) which, after settling, decays in bottom mud. Threshold odor test is method used in detg. deg. of odor. Approx. 75 tons of copper sulfate, (0.25 ppm.), used in Lake Dallas between Mar. and Aug. Several instances of temporary reduction in nos. of plankton, but little reduction in character of odor or its intensity. In Oct., drop from intensity of over 100 to below 50. Supposed that natural oxygen potential was sufficient to oxidize org.

material and decrease odor. Use of carbon in plant may be more economical than reliance on $CuSO_4$ treatment. Amt. and distr. of rainfall has remarkable influence on odor production in lake, in that high turbidities lessen org. life. —*O. M. Smith.*

Super-Chlorination. CECIL K. CALVERT. W. W. & Sew. **87:** 299 ('41). Cupri-chlorination, employing copper sulfate, Cl and ammonia (or ammonium sulfate) up to 3 ppm. each useful in presence of organisms resistant to sep. algacides; otherwise no special virtue noted by use in combination. Ammonia considered undesirable, as it furnished nutrient for aftergrowths and did not reduce copper pptn. in water of 250 ppm. alky. Sunlight rapidly dissipated chloramines. Well water with "break-point" (b-p.) at 1 ppm. Cl, largely mineral demand, showed location of b-p. nearly directly proportional to added NH_3. Residual *vs.* application curves of egg albumin and gelatin showed no b-p. and very low Cl assimilation; tryptose and peptone curves showed flat portion but no b-p. drop. NH_4Cl gave pronounced b-p.; no free NH_3 remained at b-p. Aminoacetic acid showed lazy b-p. followed by slow growth of residual. Ratio of N, as free NH_3, to Cl assimilated at b-p. varied, according to water, from 1: 7.5 to 1:20. Odor resembling NCl_3 noted beyond b-p. Cl residuals at sub-b-p. dosages combine slowly with nitrite but react rapidly above b-p. Other analytical peculiarities noted. Low temp. suppresses delineation of b-p. pattern, and increased contact time reduces Cl dosage at which min. b-p. residual appears. Coagulation of White R. water reduced b-p. by 1 ppm. Cl but straightened curvature of residual *vs.* dosage curve markedly above b-p. Sewage-poln. odors destroyed at b-p. even though accentuated by lower Cl dosages. Chlorophenol odor, in presence of NH_3, destroyed at b-p. *Synura* odor destroyed only when b-p. dose somewhat exceeded. Only spore bearers have been recovered from raw water treated with Cl in b-p. zone. Recognition of b-p. in plant control by approx. coincidence of neutral and acid thiosulfate titer at and beyond b-p.—*C.A.*

Ozone Reduces Water Odors and Tastes. ARTHUR WARDEL CONSOER AND JAMES G. NELLIS. Eng. News-Rec. **127:** 367 (Sept. 11, '41); (*see also* Jour. A.W.W.A. **33:** 2035 ('41)). Water supply of Whiting, Ind., derived from Lake Michigan, highly pold. with trade wastes and domestic sewage. Hot threshold odor no. of raw water has been as high as 275 and chlorine demand (15-min. period) as high as 50 lb. per mil.gal. The 4-mgd. treatment plant consists of spray-nozzle aerator, baffled mixing chambers and coagulation basins and 6 rapid sand filters operated at 2 gpm. per sq.ft. Avg. consumption 2.4 mgd. Alum employed for coagulation and ammonia and chlorine for sterilization. Following operation of pilot plant for 1 yr., ozonation plant consisting of five 10-lb. per day generating units installed in '40 under guarantee that treatment will reduce hot threshold no. to 6 or less when raw water no. is 30 or less, reduce it not less than 80% when no. is over 30 and under 75, and to 15 or less when no. is 75 or more, provided chlorine demand is not 35 lb. per mil.gal. or more. Contract provided that samples of ozonated water for threshold odor detn. should be collected near outlet of mixing basins, allowed to stand 6 hr., filtered through sand and allowed to stand addnl. 6 hr. before making odor tests. Contract also guarantees that excessive corrosion in distr. system will not result from treatment. During 6-mo. period, avg. ozone dosage was 11.7 and max. 43 lb. per mil.gal. Sufficient ozone applied to give trace of color with ortho-tolidine. About 0.1 ppm. ozone gives color with ortho-tolidine equal to that produced by 0.15 ppm. chlorine. Prior to use of ozone, hot threshold odor no. of tap water often as high as 40 and avgd. 15; with ozone treatment, max. has been 20 and avg. 11. Cost of ozone treatment avgd. \$2.93 per mil.gal., but reduction in amt. of alum, chlorine and ammonia required made net increase in chem. cost \$1.99 per mil.gal. Avg. cost of ozone 25¢ per lb. Including capital charges on the \$30,000 installation, maint. and increased chem. cost, total cost \$4.44 per mil.gal. No addnl. labor required. Ozonation reduces chlorine demand of water and found that higher threshold

no. satisfactory to consumers than was case before adoption of treatment. Operation of pilot plant indicated that combination of ozone and activated carbon would be effective, but in practice use of activated carbon with ozone found to reduce odor very little more than ozone alone.—*R. E. Thompson.*

Use of Ozone for Water Purification. Arthur Wardel Consoer. Civ. Eng. **11:** 701 (Dec. '41). Two of earliest munic. ozonizing plants in U.S. those at Long Beach and Hobart, Ind. Recently Denver, Pa. and Whiting, Ind., installed ozonizing plants to bring about reductions in objectionable tastes, colors and odors. Ozone produced commercially by first conditioning an air supply by cleaning and drying. Air then passed under pressure through arc or corona produced between series of dielectric plates or electrodes by discharge of a-c. of high potential. Detention period in ozonizers usually from 4 to 10 min. At Whiting, found possible to add ozone process to existing 4 mgd. rapid sand filtration plant for approx. $30,000. Avg. ozone dosage 11.7 lb. per mil.gal., and max. 43 lb. With elec. energy at $0.0123 per kwhr. and fuel gas at $0.11 per therm, addnl. cost of chems. at Whiting amtd. to $1.99 per mil.gal.—*H. E. Babbitt.*

Estimation of Plant Phenoloids in Water by the Method of Fox and Gauge. J. S. Dunn. Analyst (Br.) **66:** 105 ('41). Describes method of estg. plant phenoloids in water contg. plants, decaying logs and other vegetable matter as phenols, based on method of Fox and Gauge (J. Soc. Chem. Ind. (Br.) **41:** 173T ('22)). 50 ml. water under examn. treated in Nessler tube with 2.5 ml. 8% caustic soda soln., then with 5 ml. diazotized sulfanilic acid; after stirring, color allowed to develop for 30 min. Color obtained compared with colors of Hazen discs used with B.D.H. Nesslerizer for examn. of water; these discs found to match colors produced more nearly than did those produced by treating pure phenol. Samples contg. iron should be treated with caustic soda and filtered before use. Impounded water supply on Gold Coast, which developed obnoxious odors and tastes on chlorination, found to contain 0.31 ppm. phenoloids (estd. as phenols) in upper layers, and 0.96 ppm. at depths of 15′ to 20′. Results of detn. of phenols in cold water extracts made from plants flourishing in reservoir varied from 0.2 to 1.2 ppm. phenol. All extracts developed nauseous odors on chlorination. Phenoloids could not be extracted with chloroform. Water from reservoir treated at water works with aluminum sulfate, which reduces content of phenol from 0.31 to 0.25 ppm.; rapid filtration then lowers it to 0.18 ppm. Single filtration through bone charcoal reduced content of phenol by about 50%. Since lake was cleared of *Pistia stratiotes* (water lettuce), which gave extract contg. most phenol, and treatment with chloramine adopted in place of chlorination, objectionable tastes and odors have almost disappeared, although *Euglena*, which gave extract contg. 0.8 ppm. phenol, still flourishes.—*W.P.R.*

WATER QUALITY

Sanitary Evaluation of Private Water Supplies. Ralph L. France. Mass. Agr. Expt. Sta., Bul. 383 ('41). Bact. test for san. qual. of drinking water much more dependable and sensitive than san. chem. test. Chem. anal. of little value when applied to rural private water supplies unless several such tests can be made over considerable period of time. In Mass. no correlation between contamd. wells and spring water supplies and typhoid fever outbreaks or cases. Approx. 45% of supplies examd. shown to be contamd. by "coliform" test. —*C.A.*

For Checking Water Purity. Nathan Schnoll. Sci. Am. **165:** 127 (Sept. '41). Since elec. conductivity of water largely proportional to its deviation from chem. pure state, becomes feasible to check purity by measuring elec. conductivity.

Methods and equip. developed for use in labs., hospitals and industries for checking distd. water, steam condensate, boiler feed water and water treatment plant effluents. In case of zeolite water softener equip., possible to check condition of zeolite bed for reactivation instead of reactivating arbitrarily after a given "gallonage."—*Ralph E. Noble.*

Reporting the Results of Water Analysis. R. C. ADAMS. Proc. A.S.T.M. **40:** 1307 ('40). For purpose of selecting universal system of reporting results of water anal. which everyone can use and understand, proposed that anal. results be reported in either or both of two units: parts per million (ppm.) and equivalents per million (epm.). Ppm. defined as 1 mg. per kg. of sample or 1 lb. per 1,000,000 lb. of water. Epm. defined as a gram equivalent weight per million grams of soln.—*T. E. Larson.*

Watch Your Water Supply—It Affects Food Quality. K. G. WECKEL. Food Industries. **14:** 47 (Jan. '42). Factors in water qual. affecting food products qual. are flavor, color, turbidity, sediment, "inert" chem. properties, uniformity of compn., bact. acceptability, available vol., and acceptable temp. Every water supply, problem in itself. Practices that may be advantageously incorporated to improve them for food processing purposes are aeration to remove sulfur, oxidation and pptn. of iron, pptn. of temporary hardness, chlorination, filtration to remove turbidity, adsorption to remove odors, oxygen and chlorine removal, reaction adjustment, complete removal of hardness, and corrosiveness adjustment. Specific instances of deterioration in qual. of food or products cited in relation to neg. condition of above factors.—*Ralph E. Noble.*

The Water Works Rating System of the [Texas] State Health Department. E. H. PEARL. Tex. W. W. Short School. **22:** 62 ('40). In judging supply 3 schedules used: poln. hazards, protective measures, and quality conditions with credit points of 20, 60 and 20 respectively. Further broken down into large classification of penalties with points for each of many factors involved in hazards, protection and qual. attributes. Before approval by Eng. Div., supply must have rating of 92 points, have satisfactory monthly bact. samples and monthly reports and all responsible personnel shall have water works operators' licenses.—*O. M. Smith.*

Research and Control. NORMAN J. HOWARD. Can. Engr.—Wtr. & Sew. **80:** 17 (Jan. '42). (For previous articles of series, see Jour. A.W.W.A. **33:** 1849 ('41) and **34:** 624 ('42).) Notwithstanding fact water-borne disease steadily declined, Treasury Dept. std. of water qual. not considered sufficiently severe and is in process of revision. Outstanding changes will be increase in std. sample from 10 to 100 ml., and modification of permissible limits for copper and zinc. Stiffening of stds. conforms with present-day more critical requirements of consumers. Relationship of more severe stds. to current revision of *Standard Methods* and to deterioration of water qual. in distr. systems discussed. No sound basis for claim often made that epidemics of so-called "intestinal flu" due to water supplies, as frequency of such epidemics in cities which draw their supplies from pure sources much the same as in cities which draw their supplies from admittedly pold. sources, but employ adequate treatment. No reliable proof found of any relationship between sporadic outbreaks of intestinal disease and presence of chemically toxic substances in water supplies derived from pold. sources. Increasing attention being given to seasonal depn. of water qual. in distr. systems, which, although a most undesirable condition, never correlated with incidence of intestinal disease. If water entering system is of satisfactory qual. and possibility of secondary contamns. eliminated, aftergrowths do not appear to be of great san. signif. Only remedy appears to be maint. of stable disinfection agent in system, which is difficult problem. Open reservoirs and growths of bacteria on interior of mains possible sources of secondary growths.—*R. E. Thompson.*

Concerning the Causes of Bacterial Increase in the Distribution System of Water Supplies. H. DEUTSCHLANDER. Ztschr. Hyg. Infektionskr. **122**: 6: 639 (Nov. 22, '40). Two urban areas maintd. chlorine residual of 0.1 ppm. in water leaving works, and bact. anal. showed colony counts at 37°C. to be < 10 per ml. and no *Esch. coli* found. [Vol. tested not stated.] Examns. made in distr. systems of two townships showed great increase in colony counts, particularly in dead-ends of small mains, counts being in thousands per ml. from 4" pipes. No *Esch. coli* detected, so that deterioration not due to fecal poln. Increasing chlorine residual and flushing out of pipe systems advocated. Considerable decrease in colony counts in samples resulted. Suggested that old mains become coated with inorg. and org. deposits, and bacteria adhering to these encrustations able to thrive and multiply. Iron and manganese oxidized, ammonia oxidized to nitrite, and available energy used for multiplication. Thus, in insufficiently chlorinated water, at first decrease in bacteria due to sterilizing action of chlorine, but increase follows once chlorine utilized. Residual chlorine progressively diminishes in mains farther and farther away from pumping station, and although 0.1 ppm. appears to free water from *Esch. coli*, does not prevent multiplication of water saprophytes. Another town showed excellent anals. in water passing into supply, but deterioration took place in large bldg. where double-figured colony counts obtained from taps. Increase associated with increased temp. in bldg. due to central heating, and close association of cold, hot and central heating water pipes. Stagnation and low oxygen tension in cold water system, as water hardly ever drawn off because bldg. in use only 8 hr. of 24. Third example of deterioration outlined in impounded supply treated for plumbosolvency, and chlorinated but not filtered. During time when reservoir level low, heavy algal growth occurred, and, owing to steep incline of floor of reservoir, silt and plankton passed into distr. system and high bact. counts resulted everywhere. *Esch. coli* not present in 190 ml. amts. tested, so that poln. not dangerous, but high chlorine dosage did not produce effect until silt and algal debris washed out of pipes.—*B.H.*

TREATMENT—GENERAL

Treatment of Domestic Water Supply. D. W. HAERING Int. Eng. **81**: 23 (Jan. '42). Article relates to domestic water systems of large bldgs., institutions, hotels and hospitals. Hot and cold water systems often seriously damaged by scale and corrosion. Filtration commonest accessory but frequently installed too small and without provision for sedimentation and coagulation. Maint. frequently neglected, and periodic cleaning and sterilization omitted. Usual gamut of phys., chem., bact., and biol. conditions associated with water filtration and softening processes discussed. Point is made that glucoside derivatives (sulfoglucosate and sodium glucosate) economically effective for O_2 and CO_2 removal as pos. corrosion control. Combined carbonate pptn. control and O_2 removal accomplished with acid glucosate. Pyroglucosate prevents carbonate deposits at low dosages. Widely used with betaglucoside for scale control.—*Ralph E. Noble.*

Purification of Water With Bentonite. H. L. OLIN AND HARRY F. FREEMAN. Paper Tr. Jour. **113**: 38 (Nov. 6, '41). When dispersed as neg. charged particles in water contg. electrolytes, bentonite coagulates and forms flocs to remove suspended impurities. Coagulative effect slight in presence of monovalent cations and fairly rapid in hard waters contg. divalent calcium and/or magnesium but can be accelerated by adding trivalent aluminum or iron. In bentonite-alum split-dosage method, clay dispersion acts to remove gross material by adsorption, while alum ionizes immediately to produce trivalent cations and neutralizes and coagulates neg. charged colloidal silt remaining as residual turbidity after

main purge. Results of expts. using bentonite alone, with lime softening in split treatments; with alum, both straight and split; and with alum and lime softening described.—*Ralph E. Noble.*

Corn Cobs to Purify Water. ANON. Sci. Digest. **11:** 96 (Mar. '42) Process revealed in Patent No. 2,269,315 granted 3 research workers in Ames, Iowa, Agric. Expt. Sta. Corn cobs and other plant wastes boiled in dil. soln. of sulfuric acid, filtered and mixt. heated with caustic soda under steam pressure. Reaction mass then treated with dil. acid to ppt. lignin, the purifying agent. After treatment with 1 ppm. to remove iron and manganese, water stirred and filtered in usual way. Effective up to 10 ppm. of iron.—*Ralph E. Noble.*

Laying Large Collecting Mains in an Operating Filtered Water Reservoir. LAURENCE E. McCLUNG. Proc. 15th Ann. Conf. Md.-Del. Wtr. & Sew. Assn. ('41) p. 22. To provide better chem. treatment at McMillan plant, filtered water reservoir reconstructed to contain 36" and 48" steel collecting mains, couplings, flanges, saddles, anchorage, etc. Through a 6' x 10' opening in roof, over 1,000' of pipe and all necessary forming for over 2,000 sq.ft. concrete were placed, and men worked a mo., 24 hr. a day, in reservoir. Bact. samples taken every 4 hr. during installation period. Remarkable but true that potable effluent maintd. under conditions described. Of special interest are san. precautions taken to accomplish this: (1) all pipe, lumber, misc. material and equip. sprayed with hypochlorite soln. before lowering. Pipe sprayed inside and out, after careful removal of all dirt and extraneous matter; (2) all boats and rafts used in reservoir kept clean and covered daily or oftener with hypochlorite soln.; (3) all workmen entering reservoir, equipd. with rubber boots thoroughly cleaned with water then immediately sprayed with hypochlorite and foot bath of calcium hypochlorite maintd. at entrance for use just before entering; (4) workmen warned that improper conduct, expectorating in water or on floor inside reservoir would be dismissed. Dept. kept 2 inspectors on each shift, 1 on disinfection, other on constr. Former amply supplied with 1% calcium hypochlorite soln., prepared and tested daily; and with dry hypochlorite for sprinkling floor and rafts.—*Ralph E. Noble.*

Toronto Opens New Water Purification Plant. NORMAN J. HOWARD. Eng. Cont. Rec. **54:** 49: 8 (Dec. 3, '41). Increased consumption, which amtd. in Sept. to almost 15% over previous yr., coupled with increased operating costs occasioned by rising poln. of raw water at Island filter plants resulted in opening of Victoria Park purif. plant on Nov. 1. Water drawn from point in Lake Ont., 1½ mi. from shore, where water is 45' deep. Plant (capac. 100 mgd.) consists of mixing and coagulation basins, 20 standard rapid sand filters operated at rate of 105 mgad. (Imp.) and super- and de-chlorination equip. Alum applied by gravimetric dry feeders. At rated capac., retention period in mixing basins, of spiral flow type, 40 min., and in coagulation basins 2 hr. 50 min. Filters contain 20" of graded gravel and 26" of sand with effective size of 0.55 mm. and uniformity coef. of 1.5, and equipped with illuminated effluent comparators and rate controllers. Filtered water reservoir, located below filters, has capac. of 12 mil.gal. and retention period of 2 hr. 10 min. Super- and de-chlorination equip. consists of three 2,200-lb. and one 750-lb. manual control vacuum chlorinators and two 2,200-lb. and one 750-lb. sulfonators. Raw water pumped directly to lab. and examd. at intervals of 3 hr. Chlorinated water, pumped to chlorine control room, examd. every 30 min. Present indications are that water will be of better qual. than that at Island plants and 3 plants will be operated in such manner that best qual. of water will be available, thus effecting economies in operation and producing final product of superior qual.—*R. E. Thompson.*

Delaware Aqueduct. *X. Treatment for Delaware Water.* ANON. Eng. News-Rec. **125:** 822 (Dec. 19, '40). (For abstracts of previous articles of series see Jour. A.W.W.A. **32:** 1413, 1814 (1940)). Concluding article of series. Provisions

for treatment described. Filters designed for Croton and Catskill systems many yr. ago but, owing to excellent qual. of water delivered without filtration, have never been constructed. For last 5 yr., Catskill water, constituting about 60% of supply, has shown following avg.: turbidity, 2.2 ppm.; bacteria at 37.5°C., 6 per ml.; coliform index, 0.3 per 100 ml. Typhoid death rate avgd. 0.36 per 100,000. City owns site traversed by both Catskill and Delaware aqueducts on which filters can be built when required. In meantime, purity of Delaware supply will be assured by means proved effective for Catskill and Croton supplies. Detailed san. inspections made of all watersheds and sources of poln. eliminated. Sewerage systems and treatment works constructed, maintd. and operated for villages which constitute san. hazard. Reservoirs of project will have available capac. of 232,000 mil.gal., affording long periods of storage for sedimentation and bactericidal action. In addn., Kensico Res., with more than 30,000 mil.gal. of storage, will provide substantial detention for both Catskill and Delaware water. Taste-and-odor-producing micro-organisms in reservoirs will be controlled with copper sulfate, and facilities contemplated for continuous application when desirable. For some yr., water entering final res. of Croton system continuously treated with 1.5 lb. copper sulfate per mil.gal. This reduced yearly avg. of total organisms reaching city by 50% and practically eliminated taste-and-odor-producing organisms. Prior to water entering Kensico Res., alum and lime will be added, when necessary, for removal of occasional turbidity caused by storms. At such times, water will receive brief violent agitation by fall over weir and 30 min. gentle agitation in baffled mixing channels. Path through res. will be about 5 mi. long and anticipated time of transit about 2 wk. As water leaves res. will pass through 1,200-mgd. aerator similar to that treating Catskill water. Chlorine will be applied at 4 points. Multiple chlorination affords protection against temporary underdosing, inhibits org. growths on walls of aqueducts and tends to prevent seeding of lower reservoirs with organisms from upper reservoirs. Equip. will consist of batteries of 2,000 lb. per day vacuum-feed chlorinators. Replaceable rubber-lined and covered steel pipe will be used for chlorine soln. lines. Treatment of N.Y. supply supervised by 3 labs. about 31,000 anals. being made each yr.—*R. E. Thompson.*

The Application of Hydrogen Ion Concentration to Water Treatment. G. W. Bond. Wtr. & Wtr. Eng. (Br.) **43:** 145 (May '41), pH indicates deg. of active acidity or alky. as contrasted with total alky. or acidity detd. by ordinary titration methods. Hydrogen ion control in water treatment used primarily in clarification of turbid and colored waters by addn. of coagulants. pH control can be applied also to sterilization with chlorine or chloramine; to softening process; to protection of pipe lines; and to feed and boiler water in diminishing corrosion. Efficient coagulation (with alum) takes place at definite pH, generally under 6.0. Error of adding lime or other alkali to turbid water simultaneously with alum still common. Procedure wrong in theory and uneconomical in practice. In sodium aluminate, aluminum neg. radical, unlike alum in which aluminum is in pos. or basic radical. Because of this reaction sodium aluminate in clarification cannot be compared with alum. Optimum (pH) point in case of sodium aluminate over 10.0. In lime-soda softening process, pptn. of magnesium complete at pH of about 10.6, and of $CaCO_3$ at pH 9.5. In zeolite process, hydrogen ion concn. of brine used in regenerating important factor. pH above 7.8 leads to unsatisfactory results, while too low pH gives solvent action on zeolitic material. pH of feed water of tremendous importance for preventing corrosion. Generally speaking, higher the pH, greater the amt. of oxygen which can be tolerated in feed water. Corrosive action of acids may generally be represented by reaction $Fe + 2H^{++} = Fe^{++} + H_2$. Easier the hydrogen film is removed from surface, more readily will reaction proceed toward right. Any hydrated oxide film deposited on surface will have protective action and inhibit corrosion. *Discus-*

sion. Ibid. **43:** 252 (Aug. '41). S. STEVENS: Appears that author's references might mislead reader into assuming sodium aluminate of little use in connection with clarification of water supplies. In view of experience this impression should be corrected. When weak soln. of sodium aluminate added to natural waters, following reaction probably explains result: $Na_2Al_2O_4 + 2CO_2 + 4H_2O = 2NaHCO_3 + 2Al(OH)_3$. Proper function of sodium aluminate may be described as complementary to aluminum sulfate and should not in any case be suggested as complete alternative to aluminum sulfate for removal of color or turbidity. While quite true that use of sodium aluminate raises pH, not true to state that in case of sodium aluminate optimum point is over 10.0. Reference to pH of 10 may be due to confusing above-mentioned use of sodium aluminate in "double coagulation" with other and practical use of sodium aluminate as a coagulant in lime-soda process. Investigations tend to confirm that sodium aluminate has very definite part to play in removing color and turbidity from water supplies.—*H. E. Babbitt.*

FILTRATION

Increasing Filter Efficiency. H. NIX. Text. World. **90:** 8: 62 ('40). Performance of sand filter affected by eff. with which water previously treated, by rate at which filter operated and by condition of sand and underdrain system. When temp. of wash water above 70°F., viscosity reduced and usual rate of application not sufficient to produce necessary expansion of sand. In such cases surface wash systems can be used, or surface may be cleaned by means of h-p. hose. Samples of different layers of sand should be examd. periodically for presence of mud balls, slime, etc. Necessary to clean sand at intervals. Caustic soda widely used for this purpose; 1–2 lb. of caustic soda per sq.ft. added to water standing 12″ above top of sand, and soln. then drawn into sand bed and allowed to stand for 12–24 hr. Thorough backwashing then necessary. Sodium bisulfite may be applied in same way. Chlorine used for destroying algae and slime in sand; 1–2 ppm. chlorine may be added to wash water, or 4–8 lb. chlorinated lime per 100 sq.ft. may be added directly to surface of sand bed. Sulfur dioxide used to remove deposits of iron and manganese on sand grains. Gas sufficient to produce 2% soln. introduced into bottom of filter, and soln. allowed to stand for 6–12 hr. Cleaning action hastened by mech. agitation.—*W.P.R.*

Pressure Filters in Reinforced Concrete for an Iron Removal Plant. HANS HUGELMANN. Gas u. Wasserfach. (Ger.) **84:** 57 (Jan. 25, '41). Artesian well water supply of 770 gpm. contg. 1.4 ppm. Fe treated in pressure filters built in reinforced concrete to save on iron. Well turbine pump pushes water through filter into intermediate tank above, from which it is pumped into distr. system. Air introduced by compressor into intake of filter and relieved through automatic valve in top. Filter has inside diam. of 13′, and 6.5′ of sand of 0.5 to 1.5 mm. grain size. This gives loading of 5.7 gpm. per sq.ft. Loss of head through washed filter is 20″. Washed when loss of head reaches 10′. Highest inside water head in filter is 25′, but designed for 30′ head. Floor and roof double reinforced in top and bottom. Circular walls have ring reinforcing on outside. Sand held in place by system of reinforced concrete beams tied to walls. Recommended that, in future constructions of this type, beams should be built independently of walls, resting on consoles. Water tightness obtained by careful concrete proportioning and by using 1:2 mortar coating on inside. Two filters built to provide for future extension. One filter received inside tiling of acid proof plates. Pipes passing through walls should be concreted in with walls; at least experience was that leaks occurred only around pipes concreted in latter, through openings left in walls. Reinforced concrete tanks used only 16% of steel that would have been required for steel pressure filters of same size and cost about 15% less.—*Max Suter.*

Determination of Comparative Efficiencies of Filter Washing. Joseph Wuraftic. J.N.E.W.W.A. **55:** 411 (Sept. '41). Study of filter washing in 3 filtration plants dealing with color removal: East Providence, R.I.; Warren, R.I.; and Cambridge, Mass. Type of filters, washing method, settling retention time and supply source given for all 3 plants. Sand samples on which conclusions based taken at various depths and at various locations, to get representative sample. Brass pipe, 1" diam., used for sampling. Color test, using 3% NaOH, used in cleaning sand and detg. eff. This method preferred over other 3 used—3% H_2SO_4 soln., detn. of loss on ignition, and alum test. Results of alum test also recorded. In NaOH test, sand samples (as taken) placed in 8-oz. bottle, shaken 25 times with 200 ml. 3% NaOH soln., set aside for at least 24 hr. with several inversions; appropriate amts. of resulting color soln. dild. and compared with regular color stds. Color removal (ppm./g.) of dried, cleaned sand calcd. At Cambridge plant where top layer of filter sand very fine, 95% of dirt (as measured by color test) removed by top 5" of sand, top 1" removing 57%. At East Providence, 95% of dirt removed by top 21"; and at Warren 18" required for 95% removal. Only eff. of washing indicated, few tests giving avg. effs. of 32% for Cambridge, 84%, East Providence, and 75%, Warren, tending to show old method of washing with low velocity aided by rakes to be more efficient than other 2 methods. Author states, however, more data required for final conclusions.—*Martin E. Flentje.*

Alternating Double Filtration—A New System for the Treatment of Effluents. *Staff Report.* Chem. Age. **45:** 299 (Dec. 13, '41). Represents new method to operate percolating filters and bring about biol. purif. of sewage and trade effluents, thus reducing their poln. effect on any stream.—*Ralph E. Noble.*

Experiments With High-Rate Trickling Filters at Baltimore. C. E. Keefer and Herman Kratz Jr. Sew. Wks. J. **12:** 477 (May '40). Small section of 30 acres of trickling filter at Baltimore converted into high-rate filter by installing two 8-arm rotary distributors, each 47.5' in diam. Rate of flow to high-rate filter varied from 6.5 to 30 mgad. and anal. results compared with those from adjacent filter section equipped with Merritt square-spray nozzles on 15' centers supplied from same source of primary settled sewage at rate of 3 mgad. Flow to filters continuous. Three groups of expts. completed in '38 and '39. Authors drew following conclusions from expts.: (1) No reason to believe that ponding will occur at any rate of flow from 6.5 to 30 mgad. (2) As rate of flow increases, gradual increase in B.O.D. of effluent and decrease in nitrification can be expected. Decrease in B.O.D. removal not marked even when flow 10 mgad. (3) Even at high rates of application (26 mgad.) reduction of approx. 50% of B.O.D. of influent to filter can be expected in winter and 70% or more in summer. (4) Considerable portion of B.O.D. in summer can be removed by shallow filters from 2 to 4' deep, when rate is as high as 10 mgad. Removal undoubtedly less in winter. (5) If effluent to be better than that from sedimentation tanks and inferior to that from low-rate trickling filter, high-rate filter may serve. Treatment comparable to chem. pptn. or sedimentation and magnetite filters can be obtained by sedimentation and high-rate trickling filters. Degree of treatment depends upon rate of applying sewage and depth of filters.—*P.H.E.A.*

New Steel Filtration Plant Operating at New Britain, Conn. Anon. Am. City. **56:** 9: 62 (Sept. '41). Water for New Britain's circular steel Morse filtration plant flows by gravity from 65-mil. gal. Whigville reservoir and pumped from combined 1,420-mil.gal. Shuttle Meadow and Walcott reservoirs. Trap rock head house adjoining steel filter structure contains chem. feeders and storage rooms, mixing basin and office. Aerators, flocculators, settling basins and five 2-mgd. filters concentrically arranged around operating platform in steel filter structure. Wash water tanks installed in turret above operating platform. Used wash water conserved by settling and decanting into canal running to Shuttle Meadow reservoir.—*F. J. Maier.*

The Modernization and Enlargement of Atlanta's Filter Plant. Herman F. Wiedeman and Paul Weir. W.W. & Sew. **88:** 435 ('41). Historical review of Atlanta's water works, operating since 1875, cites Hyatt pressure-type filters of 1886-87 as one of earliest mech. installations in U.S. These units supplemented in 1893 by horizontal pressure filters operating by high head gravity feed (30'). Modern gravity type filter plant, 28.5 mgd. capac. installed in '22. Present extensions include 2 sedimentation basins having 8 mil.gal. capac. and 7 filters adding 33 mgd. to rated delivery. Counterweighted sector gates with aluminum skin plates regulate depth of water over basin outlet weirs without short circuiting. Basin discharge controlled and measured at 30" manually operated cone valve in 48" discharge lines; drop to filters is 10'. Reservoir sludge discharged through combined type sewer requiring bypassing treatment plant to prevent upsets. Filter addns. consist of one 3-mgd. and six 5-mgd. units; larger units have central gullet and are washed by sections to avoid addnl. wash-water facilities.—*C.A.*

Chemistry and Biology of the Slow Sand Filters at the Madras Water Works. S. V. Ganapati. Proc. Natl. Inst. Sci. (India) **6:** 237 ('40). Slow sand filters not suitable when applied to impounded surface water in tropics. Effluent of poor bact. qual. and contains H_2S. Under anaerobic conditions that develop in body of filter, H_2S formed by reduction of sulfates by *Spirillum desulfuricans*. In summer, H_2S content greater than loss of sulfate. Decompn. of org. S compds. does not supply difference. During winter, H_2S formed stored as FeS in filter and liberated during summer by CO_2 formed by decompn. of org. matter.—*C.A.*

SOFTENING AND IRON REMOVAL

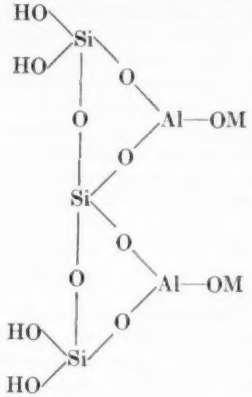
Water Softening. Ulick R. Evans. Chem. & Ind. **60:** 867 (Dec. 6, '41). Carbon dioxide in water may include: (1) CO_2 present in $CaCO_3$; (2) CO_2 needed to convert $CaCO_3$ into $CaH_2(CO_3)_2$ being numerically equivalent to CO_2 in (1); (3) addnl. CO_2 required to retain $CaH_2(CO_3)$ in soln.; (4) any CO_2 in excess of this amt. Excess constitutes *aggressive* CO_2. Tillmans and Heublein's tables show that CO_2 in (3) increases rapidly at high concns. of $CaH_2(CO_3)_2$. If hard water, rich in $CaH_2(CO_3)_2$ and previously brought into equilibrium with solid $CaCO_3$, is run through zeolite, CO_2 needed to stabilize $CaH_2(CO_3)_2$ remaining after softening will be far below hard water needs. Thus, some CO_2 in (3) will become CO_2 in (4). Water originally non-aggressive becomes aggressive. May explain cases of increased corrosive property of a water after zeolite treatment. Phenomenon may not occur, however, due to replacement of hydrogen ions by sodium ions, often undesirable from other standpoints, tending to reduce corrosiveness. Corrosive property of water contg. CO_2 in (4) due mainly to hindrance of protective carbonate film formation.—*Ralph E. Noble.*

The Theory and Practice of Base-Exchange Water Treatment. E. G. Barber. Eng. & Boiler House Rev. (Br.) **55:** 10 ('41). In softening water by base-exchange processes exact theoretical treatment of water achieved so that water contg. "zero hardness" may by obtained. No formation of any ppts. or sludge. Synthetic zeolites remove, per unit weight of material, 3 to 4 times amt. of hardness removed by "natural" mineral exchange materials; synthetic materials take longer to regenerate, but require less water for rinsing. Treatment with sodium zeolite unsuitable for acid water or water contg. iron; ferric hydroxide, which may be formed by decompn. of ferrous carbonate dissolved in water, may be deposited and cause damage by associating with base-exchange material. Optimum pH value for water to be treated with sodium zeolite between 7.0 and 9.5; waters with pH values higher than 9.5 tend to dissolve silica which, when concd. in boiler water, may be de-

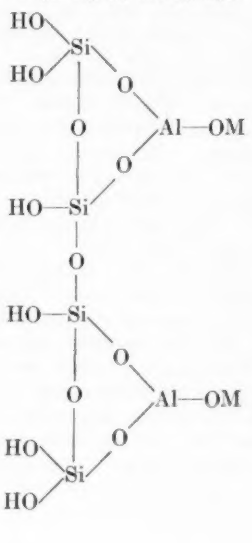
posited as scale. Carbonaceous materials regenerated with acid not affected by presence of iron or acidity. Description given of design and method of operation of different types of plant for base-exchange softening of water. Base-exchange materials can be divided into 3 main types: (1) natural greensands or glauconites which, when treated in various ways with soda, sodium silicate, etc., followed, in some cases, by roasting, produce hard, non-porous materials very resistant to wear; (2) synthetic materials made by fusion of clays, etc., with alkali or by pptn. of sodium aluminate with sodium silicate, etc., and are more porous, less hard, and generally larger in grain size and less resistant to wear than natural minerals; and (3) carbonaceous materials which are hard, black, granular materials, contg. practically no silica, and are prepd. from action of acids on coal, etc. First two types of material known as zeolites. Exchange capac. expressed as grains of hardness removed between regeneration per cu.ft. of material, should be about 2,300 for good natural zeolite and varies between 6,000 and 12,000 for synthetic zeolites. Value tends to increase with depth of bed, and in case of synthetic materials with amt. of salt used, and to decrease with increase in size of grain and with synthetic materials to vary with rate of flow. Amt. of salt required to regenerate zeolites is on avg. less than 4 times weight of hardness removed (expressed as calcium carbonate). Theory of water softening by base-exchange by zeolites and by carbonaceous materials and the reactions taking place discussed.—*W.P.R.*

Chemical Aspects of Hardness in Water and Its Removal. T. STONES. Wtr. & Eng. (Br.) **43:** 160 (June '41). Two general processes in use for softening water on large scale: lime-soda and base-exchange (zeolite). Former is oldest and most widely used. Consists of adding to water calcd. quants. of lime and soda to convert calcium salts to carbonates and magnesium salts to hydroxides. In addn. to these reagents, coagulant, such as aluminum sulfate or sodium aluminate may be added to accelerate reactions and pptn., especially of magnesium hydroxide. In addn. to deposits caused by residual suspended matters in water leaving settling tank, further tendency for deposits to form because of fact that chem. reactions continue after water leaves tank. Can be arrested by recarbonation. Most modern method of water softening is base-exchange or zeolite method. Following formulas have been assigned to active base-exchanging materials (M is an alkali metal):

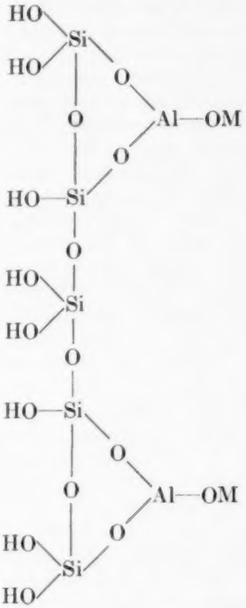
$M_2O\cdot Al_2O_3\cdot 3SiO_2\cdot 2H_2O$



$M_2O\cdot A_2lO_3\cdot 4SiO_2 3H_2O$



$M_2O \cdot Al_2O_3 \cdot 5SiO_2 \cdot 4H_2O$



Under suitable conditions alkali metal combined with aluminosilicate radical can be replaced by other metals and process is reversible:

$$Na_2O \cdot Al_2O_3 \cdot xSiO_2 \cdot yH_2O + CaCl_2 \rightleftharpoons CaO \cdot Al_2O_3 \cdot xSiO_2 \cdot yH_2O + 2NaCl$$

Zeolites of commerce can be divided into two classes—natural and synthetic. Both types sold under various trade names, e.g., natural zeolites: Borromite, Kenzelite, Natrolith, Refinite, Zepholite; synthetic zeolites: Basex, Doucil, Permutit. Advantages of zeolite process can be summarized as: (1) rapid and can be operated under pressure; (2) yields zero hardness, not obtainable in lime-soda process; (3) no adjustments required due to variations in hardness of incoming water; (4) no sludge formed; (5) wash water from regeneration clear and can be discharged into any sewer. Disadvantages: (1) Ca and Mg salts replaced by Na salts which results in increase in dissolved solids; (2) process must be interrupted periodically to revivify zeolite; (3) zeolite-softened boiler feed water apt to cause caustic embrittlement. Where waters high in temporary hardness and reduction in total dissolved solids desirable, combined process of softening by lime and zeolite can be used with advantage.—*H. E. Babbitt.*

Reduction of Mineral Content in Water With Organic Zeolites. R. F. Goudey. Proc. A.S.C.E. **68:** 225 (Feb. '42). (See also Jour. A.W.W.A. **32:** 435 ('40).) First artificial zeolites produced as solns. of sodium silicate in '06; and, in following year, reversible properties discovered. Signif. progress made in development of organic zeolites. Materials recently developed include anion exchangers for negative ion removal, which are acid- and alkali-resistant, have capac. of 29,800 grains per cu.ft. of hardness removed, rinse with about one-half water used formerly, and give twice filter runs. Regeneration with 1% NaOH or Na_2CO_3 used. Growing tendency to use carbonaceous zeolites in place of sodium zeolites, whether artificial or natural, because sodium zeolites require narrow operating limits, such as pH value from 7.0 to 7.8. In h-p. steam plant boiler feed water field, where make-up is high, evaporators would be extravagant and hydrogen zeolites offer most economical treatment. Munic. zeolite units run from $25,000 to $35,000 per mil.gal. capac., although 70-mil.gal. unit of Metropolitan Water Dist. of Southern Calif. cost only $5,000 per mil.gal. Treatment plants using hydrogen cycle require greater tank depth but considerably less area, and equip. must be made acid-proof. Should not, however, be much difference in final cost of plants for equivalent treatment capac. Waters high in bicarbonates lend themselves to high reductions in total solids through cation exchanges which, after aeration and mixing with raw waters, are not acid and may not require treatment by anion exchangers. Waters high in sulfates and chlorides usually require addn. of alkali to produce non-corrosive water if both cations and anions removed in large amts. Development of improved org. zeolites for removal of pos. and neg. ions, completely or in part, provides superior methods for

softening water, reducing sodium content, removing excess alky., lowering sulfates or reducing chlorides to produce suitable water for domestic, irrigation and industrial uses, and in special cases where inconvenience, expense, or failure to secure adequate working plan evolved. *Discussion. Ibid.* **68:** 265 (Feb. '42). James M. Montgomery: Water softening by base-exchange, using either natural or synthetic siliceous zeolites, has been practiced for many years. Org. exchange materials still in developmental stage. Synthetic resins also in developmental stage, and but few installations, some of which disappointing to both customer and mfr. Properties possessed by org. zeolites remarkable enough without some of extravagant stories told about them. When org. zeolites used for removal of anions and cations from water such as Colorado River supply, which contains large amt. of dissolved solids, quant. of rinse water required to wash excess regenerating materials from zeolite beds becomes large item. Sulfuric acid, ordinarily used for regenerating cation removal material, considerably more difficult to rinse out of zeolite bed than is salt, and both Na_2CO_3 and NaOH, usually used for regenerating anion removal material, even more difficult to rinse out than sulfuric acid. George L. Davenport Jr.: Inorg. zeolite for treatment of water used in locomotives very satisfactory for most waters of 15 gpg. hardness or less. In excess of 15 gpg., lime-soda treatment must be used. Replacement (of zeolite) relatively small. Corrosion of pipe lines and other steel surfaces coming into contact with softened water can be avoided by using about 50% more wash water than usually recommended by mfr. No convincing reason for org. zeolite use in treatment of locomotive supplies presented by mfrs. Use of inorg. zeolite appears impractical at present for railroad water softening due to high cost of apparatus and lack of skilled attendants.—*H. E. Babbitt.*

Effect of Temperature on the Exchange Capacities of Some Base-Exchange Materials Used in Water Softening. H. Ingleson and A. Harrison. J. Soc. Chem. Ind. (Br.) **60:** 87 ('41). Describes expts. to det. effect of temp. on stability and activity of various types of base-exchange materials—treated coal, treated fuller's earth, quebracho-tannin resin, imported greensand, and coarse and fine synthetic zeolites. Expts. made at room temp. and at 3.3°, 36.0°, 51.6° and 68.6°C. At higher temps. large losses of material occurred from greensand and fuller's earth owing to disintegration, soly. of siliceous materials rose steadily, and org. materials gave more deeply colored effluents. Quebracho-tannin resin appeared to be only material stable at higher temps. Base-exchange capacs. of treated coal, imported greensand and synthetic zeolites fairly constant from 3° to 51.6°C., but showed marked decrease when temp. raised to 68.6°C. Exchange capac. of treated fuller's earth fell gradually as temp. raised to 51.6°C., and considerably lower at 68.6°C. Exchange capac. of resin unaffected up to 36°C., and much greater at 51.6° and at 68.6°C. than at lower temps.—*W.P.R.*

Carbonaceous Zeolites From Bituminous Coal. S. J. Broderick and Dale Bogard. Ind. Eng. Chem. **33:** 1291 (Oct. '41). Carbonaceous zeolites passed development stage and now available commercially. New material non-siliceous, high exchange capac., rugged, and can act as hydrogen exchanger. 17 samples bituminous coals from Ky., Va., W.Va., Ala. and Ind. activated for exchange capac. by treatment with sulfur trioxide at 150°C. in revolving cylinder 3½ to 7½ hr. Exchange-capac. treated product detd. on narrow-size fraction, −28 to +35 mesh Tyler screens. When regenerated with equivalent 2.05 lb. hydrochloric acid per cu.ft. of zeolite, exchange capac. of 9,500 to 12,800 grains per cu.ft. obtained. Highest value on a W.Va., lowest on a Ky., coal. Not enough coals studied to det. relative capacs. in terms of states. Not even rough relation noted between exchange capac. and moisture, volatile matter, carbon, hydrogen, oxygen, or sulfur content of original coal; nor to total sulfur in final treated material.—*Ralph E. Noble.*

Carbonaceous Cation Exchangers From Coal and Coal Refuse. S. J. BRODERICK AND DALE BOGARD. U. S. Bur. Mines, Rept. Investigations 3559 ('41). Use of Alabama bituminous coal mine waste as raw material for making granular water softening product not feasible because of high loss of fines resulting from activation treatment. Both clay and coal fractions of refuse show distinct base-exchange properties. Clay portion activated into base-exchange product with alkali; coal activated into H-exchanger with concd. H_2SO_4. Coal more active cation exchanger than clay for water softening. No direct correlation between capacities of base-exchange product and tendency to pulverize. Highest exchange capac. developed by concd. H_2SO_4 digestion followed (after washing) by autoclaving with dil. NaOH. Highest Na-exchange capac. obtained 6,000–6,500 grains per cu.ft.; H-exchange capacity was 7,000–7,500 grains. Na in raw water reduced capac. considerably; 3.7% of total cations as Na reduced capac. of H-exchanger from 7,500 to 6,400 grains per cu.ft. At 33.3% Na, capac. seemed to have reached const. value of approx. 4,000 grains.—*C.A.*

Organic Base-Exchangers on Mineral Supports. CARLOS S. DE LA SERNA. Industria y Quim. (Argentina) **3:** 68 ('41). Pumice crushed, sieved to 20–40 mesh, mixed with concd. H_2SO_4, warmed to 70° and slurry of finely powd. quebracho extract in H_2SO_4 slowly added to mixt. Plastic mass maintd. at 80° for 1 hr., cooled, washed, dried at 110° and sized between 20 and 40 mesh. Product has excellent softening action on hard waters and can be regenerated with 10% soln. of NaCl.—*C.A.*

Economical Method of Base-Exchange Water Softening. ANON. Eng. Cont. Rec. **55:** 4: 13 (Jan. 28, '42). Basex (Paterson Eng. Co., London) is synthetic zeolite consisting of hard white translucent granules of compn. approxg. formula: $Na_2O \cdot Al_2O_3 \cdot 14SiO_2$. Material weighs 51 lb. per cu.ft. and exchange capac. exceeds 10,000 grains hardness ($CaCO_3$) per cu.ft. Strongly resistant to solvent action of water and carbon dioxide, and grains retain their shape and sharp edges. With bed 3′ deep, flow rate of 5 gpm./sq.ft. easily maintd., with considerable margin for overloads. With ordinary single-flow regeneration, salt required is 0.45–0.5 lb. per 1,000 grains hardness ($CaCO_3$) removed. Brine contg. 5–7% sodium chloride employed. If spent brine re-used, completing regeneration with fresh brine, salt consumption can be reduced to 0.31–0.35 lb. per 1,000 grains removed and with great care to 0.28 lb.—*R. E. Thompson.*

Base-Exchange Material. HAROLD NIELSON AND AKTIESELSKABET FAERÖ-KUL. Br. Pat. 519,872 (Apr. 9, '40). Ion-exchange material made from non-plastic variety of clays such as those found in Faroe Islands by subjecting raw material to regulated heat-drying treatment, slacking dried material with water to granulate it, removing undesirable large pieces of slacked material, and removing fines from remaining granular material.—*C.A.*

Zeolite Water Softening With Anti-Corrosion Control. ANON. Am. City. **56:** 10: 50 (Oct. '41). Softening plant at Grinnel, Iowa, treats well water having hardness of 513 ppm. Two 400-gpm. "Elgin" softeners with artificial zeolite reduce hardness to zero. Mixed with raw water, delivered water contains about 85 ppm. hardness. Plant complete with automatic regenerative equip. Prior to softening, 6″ mains had up to 1″ deposits. Caustic soda treatment and flushing have since removed most incrustations.—*F. J. Maier.*

Reconditioning Zeolites—Commercial Process Evolved. ANON. Chem. Age. **45:** 285 (Dec. 6, '41). So far, less than 50% restoration of original exchange (exch.) capac. obtained from zeolites reconditioned by treatment with dilute acids or salt solns. Australian greensand chem. treated for exch. value of 5,500 grains $CaCO_3$ per cu.ft. used for water softening 5 yr. Water to be softened pretreated by lime. Zeolite, fully contamd. with $CaCO_3$, iron oxide and org. matter, lost its exch. and regeneration properties. Such greensand

considered worthless. To recondition it, material put through 20- then 60-mesh sieves. Thus 15% discarded. Remainder treated 30 min. with 30% H_2SO_4 at 100°C.; then washed till wash water clear. Material next treated 1 hr. with 60% H_2SO_4 at 100°C. Intimate contact with acid maintd. After further washing acid free, material dried, then treated with alk. sodium aluminate contg. also preferably NaCl. Intimate contact maintd. After heating 20 min. at 100°C., excess alky. removed by washing. Greensand then stabilized with 2% soln. sodium silicate followed by 2% aluminum sulfate. Ready for use. Comparative tests of zeolites thus reconditioned, and new zeolites, showed former stable with same exch. value as new material.—*Ralph E. Noble.*

Reconditioning Zeolites Which Have Lost Exchange Capacity Due to Contamination. A. KLEIN. J. Soc. Chem. Ind. **60:** 10: 262 ('41). Spent zeolite first screened to remove both gravel and fine dust. Then treated with 30% H_2SO_4 at 100° for approx. 30 min., washed well, treated with 60% H_2SO_4 at 100° for 1 hr., and washed free from acid. Material then dried and treated with alk. soln. of Na aluminate contg. NaCl. Dried by heating 20 min. at 100°, then washed to remove excess alkali. Then stabilized by treatment with a 2% soln. of Na silicate followed by a soln. of $Al_2(SO_4)_3$. Australian greensand originally chemically treated for exchange capac. of 5,500 grains $CaCO_3$ per cu.ft. which had entirely lost exchange capac. completely regenerated by this treatment. —*C.A.*

Water Softening With Bleaching Soda. BRUNO WALTHER. Deut. Wascherie-Forsch. (Ger.) **7:** 152 ('39); Chem. Zentr. (Ger.) **I:** 2408 ('40). Expts. reported on softening of water at different temps. with calcined soda and bleaching soda (about 50% Na_2CO_3, 7-8% water glass as dry wt., phosphates and water). Softening action of bleaching soda more rapid than that of calcined. Particularly true at lower temps. and temps. (about 25°) used in washing in machines. Precipitates obtained with bleaching soda finely dispersed. When calcined soda used, reaction took place slowly and addn. of soap produced rapid reverse reaction leading to formation of Ca soaps. Waters treated with calcined soda formed suds only with difficulty and larger amts. required, while waters treated with bleaching soda formed suds readily.—*C.A.*

Softening Water With Non-Metallic Minerals. S. J. BRODERICK. U. S. Bur. Mines, Rept. Investigations 3578 ('41). Use of following in coagulation and H_2O softening reviewed: kaolin, fuller's earth, bentonite, alum, $FeCl_3$, $Fe_2(SO_4)_3$, $FeSO_4$, chlorinated copperas, ferric-alumina, Na silicate, Na aluminate, Na zincate, Ti salts, lime-soda, Na hexametaphosphate, zeolites, lignite, clay, etc.—*C.A.*

Tetrasodium Pyrophosphate. ANDREAS TREFFLER. Soap, San. Chems. 17: 29 (Nov. '41). In neutral solns., water softening eff. of sodium metaphosphate (smp.) about **7** times greater than tetrasodium pyrophosphate (tspp.). In alk. solns., about 4 times greater because smp., having acid reaction, decomposes somewhat by neutralization in such solns. At higher temps., smp. decomposes slowly in neutral solns., faster in alk. solns., in addn. to such decompn. by neutralization. Heat and any large amt. impurities speed complete decompn. within few hr. Tspp. remains unchanged during prolonged boiling. Its water softening strength and detergent value improved in presence other alkalies. In certain cases only tspp./alk. mixtures advisable. —*Ralph E. Noble.*

Phosphates in Water Conditioning. CHARLES SCHWARTZ AND C. J. MUNTER. Ind. Eng. Chem. **34:** 32 (Jan. '42). By '30 phosphate compds. had established position in water treatment largely due to use of hydrated trisodium phosphate in boiler water conditioning and as detergent, though other orthophosphates and tetrasodium pyrophosphate also commercially available and used to some extent. Since then, use of "molecularly dehydrated phosphates" has been de-

veloped. Polyphosphates have general formula [n H_3PO_4 — (n — 1) H_2O] with values of n up to 10 in some salts reported; polymetaphosphates have general formula [n H_3PO_4 — n H_2O] with values up to n = 14 reported. Although salts of only 3 exist in crystalline state, various other nominal compositions from meta- nearly to pyro- occur as glasses. New phosphates used in water conditioning come from this class, though orthophosphates still used as well as cryst. tetrasodium pyrophosphate. Glasses contain 60 to 69% P_2O_5. Known phosphate compds. range from strongly acid to strongly alk.; in glasses, nominal composition correlates well with titration curve. Phosphates also differ in reactions with metals, glasses surpassing in formation of complexes. They give no pptn. at low concns. of metal ions regardless of pH, but excess of phosphate prevents pptn. and redissolves any ppt. formed. This complex formation enables their use to prevent feed line deposits in boilers, etc. Effectiveness for holding Ca ions against pptg. agents varies with P_2O_5 content of glass used. Low concns. of these agents in range of less than one up to a few ppm. prevent pptn. of troublesome compds. from waters. Amt. needed so far below that needed for complete complex formation with metal ions present, that term "threshold effect" coined. Amt. of reagent should be carefully controlled since excess is unnecessary waste. Increase in alky. and temp. necessitates increased dosages. Closely related to "threshold effect" is ability of low concns. of glasses to be adsorbed on metal surfaces where they decrease corrosion, and on insoluble compds. involving metal ions where they have "dispersing effect." Phosphates, old and new included, have ability to: (1) provide acid, neutral or alk. solns. for control of pH value by both neutralization and buffer action; (2) act as emulsifying agents; (3) reduce metal ion concn. by pptn. or complex formation; (4) reduce alky. by hydrolysis to orthophosphate; (5) stabilize solns. supersatd. with respect ordinarily insoluble salts; (6) form adsorbed films on metal surfaces; (7) disperse insoluble compds. through adsorption on solid particles. Proper treatment of boiler water with phosphate involves maintenance of enough PO_4 ion and enough but not excessive alky. to ppt. $Ca_3(PO_4)_2$ as sludge instead of $CaSO_4$ as scale. Chief difficulties are high alky. of tetrasodium pyrophosphate and pptn. of residual Ca in feed lines and economizers. Addn. of molecularly dehydrated phosphates into feed line prevents this after-pptn. Phosphate can also be used for presoftening of all make-up water. Protection of high pressure boilers almost universally attained by PO_4 treatment of boiler water; without their use, power plant efficiency would lag far behind present attainments. Phosphates have numerous applications in textile processing. In munic. and process water treatment, threshold treatment with glassy phosphate prevents pptn. and scaling of lines, prevents corrosion, stabilizes unstable waters against pptn. when heated or chemically treated, and minimizes red water from hot water heaters. Phosphates also have a variety of uses as detergents, and in miscellaneous uses. Bibliography of 97 titles.—*Selma Gottlieb.*

St. Paul Softens Water Cheaply. Ross A. Thuma. Eng. News-Rec. **127:** 228 (Aug. 14, '41). Water supply derived from Mississippi R., passing through 13-mi. conduit, 3-mi. open canal and 4 storage lakes with capac. of 6 billion gal. Softening facilities added to purif. plant late in '39. After addition of lime and alum (5–10 min. interval), water aerated with compressed air for odor removal, passed through baffled chamber, flocculator and clarifier then recarbonated and filtered. Ammonium sulfate applied prior to filtration and chlorine and second dosage of carbon dioxide, derived from stack gases, after filtration. Sufficient lime applied to give 15–30 ppm. caustic and normal carbonate alky., and pH reduced to 9.0 prior to filtration and to 7.5 in clear wells. Water with caustic alky. tends to extract moisture from mucous membranes of mouth and produces sensation of thirst. Unfavorable comments about inability of water to quench thirst dis-

appeared when practice of reducing pH to 7.5 was adopted. Addn. of returned sludge to lime suspension results in 12–15% saving in lime, although active lime content of sludge is nil. During first 6 mo. operation, trouble experienced due to old scale being dislodged from distr. system. During '40, total hardness reduced from 172 to 87 ppm. at addnl. cost of chems. of $3.51 per mil.gal. Only 10% of raw water hardness noncarbonate. Assuming that soap at avg. cost of 15¢ per lb. used with 2% of water consumed, saving in soap alone as result of softening estd. at $14.75 per mil.gal. Total saving probably double this amt. —*R. E. Thompson.*

Double Cone Precipitators Soften Water at Minneapolis. J. ARTHUR JENSEN. Eng. News-Rec. **127**: 372 (Sept. 11, '41). Since '13, Minneapolis supply coagulated with alum, filtered and sterilized with chlorine. Two filter plants, one at Columbia Heights and other at Fridley, with combined capac. of 158 mgd. Chloramine treatment and activated carbon used as conditions require for alleviating taste and odor. In June, lime softening plant consisting of 12 double cone precipitators of 10-mgd. capac. each and carbonation chamber placed in commission on Mississippi R. at Fridley. Hardness will be reduced from avg. of 175 to 75 ppm. and color from avg. of 35 to not more than 10 ppm. Expts. have indicated that normal lime treatment will reduce color to 10 ppm. if raw water color does not exceed 75, which occurs about 24 days each yr. Normally, water will be softened and delivered to 2 filter plants, but when color exceeds 75–90 ppm., it will be treated with alum in coagulation basin of Fridley filter plant to reduce color to about 75, flow to softening plant for lime treatment and recarbonation and then be delivered to filter plants. Estd. that saving in soap effected by softening will be $0.95 per capita per yr. On this basis, saving in soap will triple cost of softening. Cost of plant was $3,973,500. Softening received with universal approval, except that owners of goldfish complain that softened water will not sustain these fish.—*R. E. Thompson.*

Minneapolis Softens City Water. J. ARTHUR JENSEN. Minn. Municipalities. **26**: 372 (Sept. '41). Minneapolis takes raw water from Mississippi R. City first built Columbia Hts. filtration plant then treated water with hypochlorite of lime, then filtration plant, later liquid Cl, and in '27 Minneapolis added filtration plant to treatment system. In past year, 120 mgd. softening plant put in operation, having 12 Spaulding type precipitators. Pumped water metered to chem. house where lime with auxiliary treatment applied. After treatment clear top water overflows circular weir and passes to carbonation chambers. Softening of water has both qual. and economic advantages. Water softening and filtration are elimination processes. None of reagents employed remain in water; alum and lime ppt. sweep out turbidities, algae and undesirable minerals. Soap has little cleansing power until calcium and magnesium salts neutralized, annual soap saving with softened water about 3 times cost of lime softening, besides lime, effective and economical germicide. Authority of Univ. of Ill. demonstrated that soap costs varied in proportion to water hardness. At present pop., estd. softening will save consumers annually $451,000. Hardness of 75 ppm. economic min. Softened water precludes boiler scale, longer life to clothing by reason of milder suds. Preliminary ests. of cost of treatment per mil.gal. is $20.52, filtration $13.51, softening $7.01. Public reaction favorable. Cities with softened water can assure industries of reduced operating costs.—*Samuel A. Evans.*

Softening Water. EGON ZENTNER. U. S. Pat. 2,259,717 (Oct. 21 '41). App described, and process for pptg. hardness constituents on cores of contact material which involves adding to hard water a softening chem. such as a lime soln. and immediately passing water contg. such added chem. upwardly through bed of granular contact material such as calcite at velocity sufficient to maint. contact material in substantially continuous motion.—*C.A.*

TITLE 32—NATIONAL DEFENSE

Chapter IX—War Production Board

Subchapter B—Division of Industry Operations

Part 1075—Construction

CONSERVATION ORDER NO. L-41

The War Production Board on April 9, 1942 called a halt to non-essential construction.

Effective immediately, Conservation Order L-41 prohibited the start of unauthorized construction projects which use material and construction equipment needed in the war effort. It also placed all new publicly and privately financed construction under rigid control, except for certain strictly limited categories.

The action was taken by the WPB because the war requirements of the United States have created a shortage of materials for war production and construction. It is in the national interest, the Board stated, that all construction which is not essential, directly or indirectly, to the successful prosecution of the war, and which involves the use of labor, material or equipment urgently needed in the war effort, be deferred for the duration of the emergency.

Many of the same materials, such as iron, steel and copper, are used by both essential and non-essential construction, and the same materials are largely used for war production. Since there is not enough of these materials for both war production and for less essential use, the order, in effect, allocates these materials away from unnecessary construction, and into ships, planes, tanks, guns, defense housing and other essential production.

This step goes much further than the SPAB policy announcement of Oct. 9, 1941. In that announcement, it was made clear that no priority assistance would be given to non-essential construction. In this order, however, it is provided that no construction may be started (except in a few specified cases) without permission.

Equally binding upon property owners, builders and suppliers, the order prohibits not only the start of construction in most categories, but also the withdrawal from inventory and the purchase, sale or delivery of any

material for use in such construction unless expressly authorized by the War Production Board.

The order specifically provides that no residential construction except for maintenance and repair work may be started without permission if its estimated cost is $500 or more. Similarly, no new agricultural construction may be started if the estimated cost is $1,000 or more for the particular building or project involved. No other construction, including commercial, industrial, recreational, institutional, highway, roadway, sub-surface and utilities construction, whether publicly or privately financed, may be initiated without permission if the cost of the project amounts to $5,000 or more.

In computing such costs, the amount spent on the project within 12 months of the date of beginning construction, and subsequent to April 7, 1942, is included.

Specific types of construction, however, are necessarily exempt from the provisions of the order. These include:

1. Projects which will be the property of the Army, Navy, Coast Guard, Maritime Commission and certain other listed agencies of the Federal Government;

2. Projects to reconstruct or restore residential property damaged or destroyed on or after January 1, 1942, by fire, flood, tornado, earthquake or the public enemy.

3. Projects of the type restricted or controlled by provisions of the orders of the M-68 series, which cover the production and distribution of petroleum.

It was emphasized, however, that the order does not affect ordinary maintenance and repair work to return a structure to sound working condition without a change of design.

Officials charged with the administration of the L-41 order are considering a plan to issue to authorized projects an emblem or insignia to be conspicuously posted on the job to show that the construction has been approved by the War Production Board.

Although the order applies only to construction not yet commenced, projects already under construction are being carefully examined by the War Production Board on an individual basis. Such projects may be stopped if the scarce materials to be used in them can be put to more effective use in the war program.

Where priority assistance is granted by the War Production Board, authority to commence construction will be issued by the Director of Industry Operations on appropriate forms of orders in the P series.

These include preference rating orders of the P-14 series, P-19 series, P-41, P-46, P-55, P-98, P-110 and P-115. (See appended Schedule A for types of construction). Preference ratings extended on PD-1 or PD-1A forms or by any other P order than those listed in the L-41 order do not constitute authorization to begin construction.

Facilities on the Federal Housing Administration have been made available to the War Production Board in the administration of this order and applications or authority to start construction will be filed with the local offices of the Federal Housing Administration on Forms PD-200 and PD-200A, copies of which may be obtained at any of the district War Production Board offices or at any local office of the Federal Housing Administration. The public is urged to file only emergency applications during the next month, as it is anticipated that authorization will be given only for emergency projects. Authority to begin construction will be granted only when the design and specifications conform with the standards established for the minimum use of critical materials, and no materials will be used on the project that do not conform with the conditions of the authorization granted to begin construction.

On the basis of criteria established by the Director of Industry Operations of the War Production Board, the local officer of the Federal Housing Administration will decide whether or not the project is eligible for recommendation to the War Production Board. If the project is deemed eligible, the application will be forwarded by the Federal Housing Administration to the administrator of the order for final consideration.

If the application is denied by the local Federal Housing Administration office, based on the WPB criteria, provision is made for an appeal to an appeals board to consist of the administrator of the order, a representative of labor and a third member who will represent the end product branch of the War Production Board within whose jurisdiction the class of project or construction would fall.

CONSERVATION ORDER NO. L-41

War requirements of the United States have created a shortage of all materials required for war production and construction necessary thereto, for private account and for export; the War Production Board accordingly has stated as its policy that it is in the national interest that all construction which is not essential, directly or indirectly, to the successful prosecution of the war, and which involves the utilization of labor, material or construction plant urgently needed in the war effort, be deferred for the duration of the emergency; the following order is, therefore, necessary and appropriate in the public interest to conserve scarce materials by allocating them to essential uses and restricting their use in non-essential construction.

Section 1075.1—CONSERVATION ORDER NO. L-41

(a) *Definitions.* For the purpose of this Order

(1) "Person" means any individual, partnership, association, business trust, corporation, governmental corporation or agency, or any organized group of persons, whether incorporated or not.

(2) "Construction" means the erection, construction, remodeling or rehabilitation of any building, structure or project, or additions thereto or extensions or alterations thereof, but not including maintenance or repair as defined in paragraphs (a) (8) and (a) (9) below.

(3) "Residential Construction" means any Construction where the principal function of the building, structure or project is or will be to provide living space or accommodations, including, but not limited to, single or multiple dwelling units, dormitories, hotels, and apartment houses.

(4) "Agricultural Construction" means any Construction, other than Residential Construction, where the building, structure or project is used in the production of agricultural products, including, but not limited to, those produced by farmers, planters, ranchmen, dairymen, or nut or fruit growers.

(5) "Other Restricted Construction" means any Construction, other than Residential and Agricultural Construction, including, but not limited to, commercial, industrial, recreational, institutional, highway, roadway, sub-surface and utilities construction, whether publicly or privately financed.

(6) "Begin Construction" means to initiate Construction by physically incorporating into any Construction material which is an integral part of the Construction.

(7) "Cost" is meant to include the total cost of labor and material, including equipment, architects', engineers', and contractors' fees, insurance charges and financing costs.

(8) "Maintenance" means the upkeep of a building, structure or project in sound working condition.

(9) "Repair" means the restoration, without change of design, of any portion of a building, structure or project to sound working condition, when such portion has been rendered unsafe or unfit for service by wear and tear, damage or other similar causes.

(b) *Prohibited Construction.* No Person shall, after the date of issuance of this Order, begin construction or order, purchase, accept delivery of, withdraw from inventory or in any other manner secure or use material or construction plant in order to Begin Construction, unless the Construction is within one of the following classes:

(1) The Construction is to be the property of the Army or Navy of the United States, the United States Maritime Commission, the Panama Canal, the Coast and Geodetic Survey, the Coast Guard, the Civil Aeronautics Authority, or the Office of Scientific Research and Development.

(2) The Construction consists of any building, structure or project which is used directly in the discovery, development or depletion of mineral deposits.

(3) The Construction is of a type subject to the provisions of any order in the M-68 series relating to the production and distribution of petroleum. Any such construction is permitted only to the extent authorized by the applicable order in the M-68 series.

(4) The Construction is Residential and
   (i) the estimated Cost is less than five hundred dollars; or
   (ii) is to reconstruct or restore Residential Construction damaged or destroyed after December 31, 1941, by fire, flood, tornado, earthquake, act of God or the public enemy.

(5) The Construction is Agricultural and the estimated Cost is less than one thousand dollars.

(6) The Construction is Other Restricted Construction and the estimated Cost is less than five thousand dollars.

(7) The Construction has been or is hereafter authorized by the Director of Priorities of the Office of Production Management or by the Director of Industry Operations by the issuance of
   (i) one of the Preference Rating Orders or Certificates listed on Schedule A appended hereto, as that Schedule may be amended from time to time, according priorities assistance to the Construction; or
   (ii) an order specifically authorizing the Construction.

Provided, however, that the exceptions set forth in paragraphs (b) (4) (1), (b) (5), and (b) (6) shall not be construed to authorize separate or successive Construction operations the aggregate Cost of which over any continuous twelve-month period exceeds the amount specified in the applicable paragraph for the particular building, structure or project.

(c) *Prohibited Deliveries.* No Person shall accept an order for, sell, deliver, or cause to be delivered, material or construction plant which he knows, or has reason to believe, will be used in violation of the terms of this Order.

(d) *Further Construction Limitations.* Nothing in this Order shall be here construed to authorize the use or delivery of any material, or the application or extension of any preference rating, in violation of the provisions of any

conservation, limitation or other order or regulation heretofore or hereafter issued by the Director of Priorities, Office of Production Management, or by the Director of Industry Operations.

(e) *Orders or Certificates Not Constituting Authorization.* The assignment of a preference rating by a PD-1, PD-1A or other certificate, or by any order other than those listed in Schedule A, shall not constitute authorization to Begin Construction.

(f) *Applications for Authority to Begin Construction.*

(1) If the applicant requires priorities assistance for the proposed construction, an application shall be made for the appropriate Preference Rating Order or Certificate listed on Schedule A on the form referred to therein.

(2) Where the applicant does not require priorities assistance, application for the specific authorization to begin Construction referred to in Paragraph (b) (7) (ii) hereof may be made by filing Forms PD-200 and PD-200A, or such other forms as may hereafter be prescribed, together with a statement showing (1) that no priorities assistance is requested, (2) whether any previous application for authorization has been denied, and, if so, the reasons therefor, and (3) the total value of all Construction on the particular building structure or project in the preceding twelve-month period. Such forms or statements are to be filed with the field office of the Federal Housing Administration having jurisdiction over the location of the site.

(3) In Applying either for priority assistance or for authorization to Begin Construction, the applicant should also submit additional information as to the necessity for the proposed construction, any exceptional hardships which the restrictions of this Order impose upon him, the effect on employment conditions if the application is denied, and any other pertinent facts.

(g) *Violations.* Any person who wilfully violates any provision of this Order or who wilfully furnishes false information to the Director of Industry Operations in connection with this Order is guilty of a crime, and upon conviction may be punished by fine or imprisonment. In addition, any such person may be prohibited from making or obtaining further deliveries or from processing or using material under priority control and may be deprived of priorities assistance by the Director of Industry Operations.

(h) *Communications.* Applications, communications and reports under this Order shall, unless otherwise directed, be addressed to:

War Production Board
Washington, D. C. Ref: L-41

Those relating to Residential Construction shall in addition be conspicuously marked "Res.," those relating to Agricultural Construction "Agr.," and those relating to Other Restricted Construction, "O.R."

(i) *Effective Date.* This order shall take effect immediately.

Issued this 9th day of April, 1942.

(signed)
J. S. KNOWLSON,
Director of Industry Operations

SCHEDULE A—CONSERVATION ORDER L-41

The following Preference Rating Orders and Certificates are listed pursuant to paragraph (b) (7) (i) of the above Order. A general description of the type of construction covered by each, the appropriate application form and where such form should be filed, are given solely for purposes of identification.

Preference Rating Order	*Type of Construction*	*Application Forms*	*Where Filed*
P-14-a P-14-b	Shipyards and shipways	No form	Maritime Commission, Washington, D.C.
P-19 P-19-a	Buildings, structures and projects important to the war effort and essential civilian needs, other than housing	No further application accepted under P-19 and P-19-a. Apply for P-19-h or P-19-i	
P-19-d P-19-g	Publicly financed housing	Application is made only by the federal agency principally interested in the construction	————
P-19-e	Public roads	Application is made by or through the Public Roads Administration of PWA	————
P-19-h P-19-i	Buildings, structures and projects important to the war effort and essential civilian needs other than housing	Forms PD-200 and PD-200A	With the field office of FHA having jurisdiction over the location of the site
P-41	Construction of air transport facilities	See Order	————

Preference Rating Order	*Type of Construction*	*Application Forms*	*Where Filed*
P-46	Certain types of utilities construction	See Order	———————
P-55 P-55 amended	Privately financed defense housing	Form PD-105	With the field office of FHA having jurisdiction over location of the site
P-98	Construction related to petroleum enterprises as defined and limited therein	See Orders in M-68 series	———————
P-110	Remodeling of housing in defense areas	Form PD-406	With field office of FHA having jurisdiction over the location of the site
P-115	Expansion of canning plants	Form PD-285	With WPB, Washington
Certificates			
PD-3 PD-3A	Principally buildings, structures and projects owned or to be owned by the Army, Navy or certain other governmental agencies	Form PD-3A	With the contracting or procurement official having jurisdiction over the contract